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ENDRIN POLLUTION IN THE LOWER MISSISSIPPI RIVER BASIN

Federal Water Pollution Control Administration
Baton Rouge, Louisiana

June 1969

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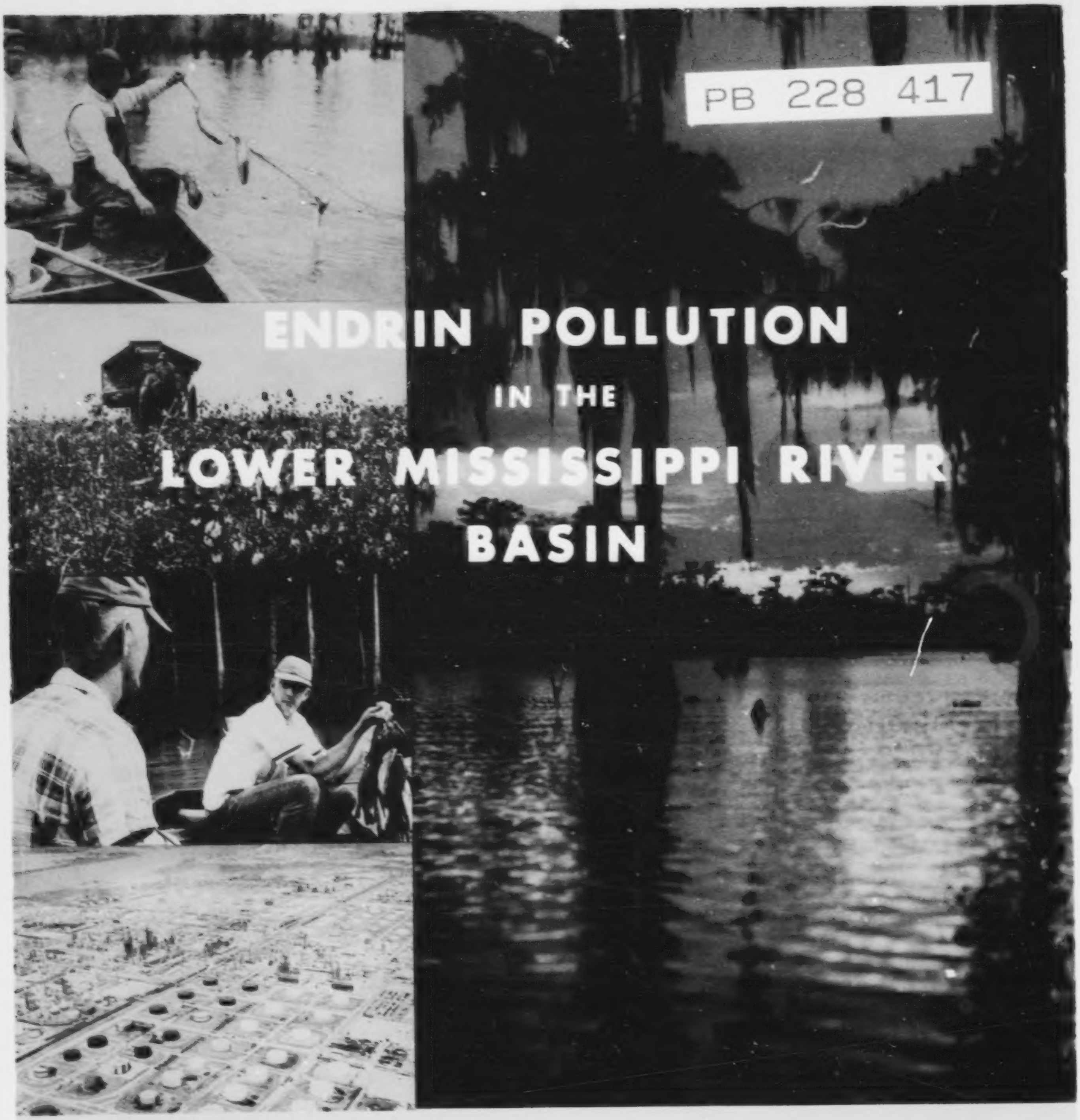

ENDRIN POLLUTION

IN THE

LOWER MISSISSIPPI RIVER BASIN

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UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region Dallas, Texas

June 1969

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ENDRIN POLLUTION
IN THE
LOWER MISSISSIPPI RIVER BASIN

U. S. Department of the Interior
Federal Water Pollution Control Administration
Lower Mississippi River Technical Assistance Project
Baton Rouge, Louisiana

June 1969

FOREWORD

In late October 1963, reports of fish "acting crazy" and dying in both the Mississippi River, as it flows through Louisiana, and in the Atchafalaya River, were received by the Louisiana Wild Life and Fisheries Commission, Division of Water Pollution Control, located in Baton Rouge, Louisiana. It was the beginning of a phenomenon that, since the fall of 1960, had become annual. Louisiana State Water Pollution Control personnel had, in earlier years, called upon various State and Federal organizations for assistance in explaining the kills. Still the phenomenon eluded defensible explanations. Concern about the situation intensified during the first two weeks in November because the incoming reports of these mortalities contained estimations of numbers of dying fish exceeding those recorded by the State in previous years. The dieoff pattern was the same as before, and whatever was killing the fish was again species preferential both in the fresh and estuarine waters.

When the State began to receive reports of similar kills in the river from areas upstream from Louisiana, a request for assistance was made to the Division of Water Supply and Pollution Control, United States Public Health Service, in Washington, D. C. Fish mortalities in the Mississippi River near Baton Rouge, Louisiana and in the estuarine areas near Venice, Louisiana were investigated and laboratory studies were conducted in Cincinnati. Results of these studies supported an earlier conclusion of Louisiana State authorities that the pesticide endrin was responsible for the 1963-64 catastrophic fish kills in the Lower Mississippi River system.

On the basis of this conclusion, the State of Louisiana and the Secretary, Department of Health, Education, and Welfare took the following actions: (1) in April 1964, the Chairman, Louisiana Stream Control Commission, formally requested technical assistance from the U. S. Public Health Service; (2) at the call of the Secretary of Health, Education and Welfare, a water pollution control enforcement conference was convened in New Orleans, Louisiana on May 5, 1964, under the Federal Water Pollution Control Act. This conference was concerned with interstate pollution of the Mississippi River and tributaries from the northern border of Arkansas to the mouth of the river. The conferees recommended that known sources of endrin discharges from industry, land drainage, and mud deposits be brought under control immediately and other sources of endrin pollution be identified and brought under control as soon as possible.

The conferees also recommended that a Technical Committee be established, comprising the conferees or their designees, "to advise in the identification and abatement of all sources of pollution affecting the main stem of the Lower Mississippi." An Interagency Coordinating Committee was also established.*

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* Membership of both committees appear in the Appendix, Exhibit A.

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INTRODUCTION

Authority

In response to the State of Louisiana's request for technical assistance, and, in accord with recommendations of the May 5-6, 1964, Enforcement Conference, the U. S. Public Health Service initiated the Lower Mississippi River Technical Assistance Project with headquarters at Baton Rouge, Louisiana. This investigation was made under the authority of the Federal Water Pollution Control Act, as amended (U.S.C. 433, Sect. 5 (b)).

Scope

The study area comprised the main stem of the Mississippi River from Hickman, Kentucky, to the Gulf estuaries, the major tributaries in this system, the Atchafalaya River (the Mississippi River's distributary) and associated estuaries (Figure 1).

The intensive study period was for three years, beginning in October 1964, and concluding at the end of September 1967. In addition, the fish study and monitoring of the waste discharges from the Velsicol Chemical Corporation, Memphis, Tennessee, continued through December 1968.

Objectives

The long range objective of the Lower Mississippi Technical Assistance Project was the development of a program of correction and future prevention of surface and ground water degradation resulting from discharges of organic pesticides and other pollutants into the waters of the Lower Mississippi and its tributaries. Specific objectives, established in consultation with the Technical Advisory Committee, were:

1. To determine the extent and pattern of endrin pollution of the surface and ground water resources of the Lower Mississippi River Basin;
2. To determine the extent and pattern of endrin contamination of fish, shellfish, and public water supplies;

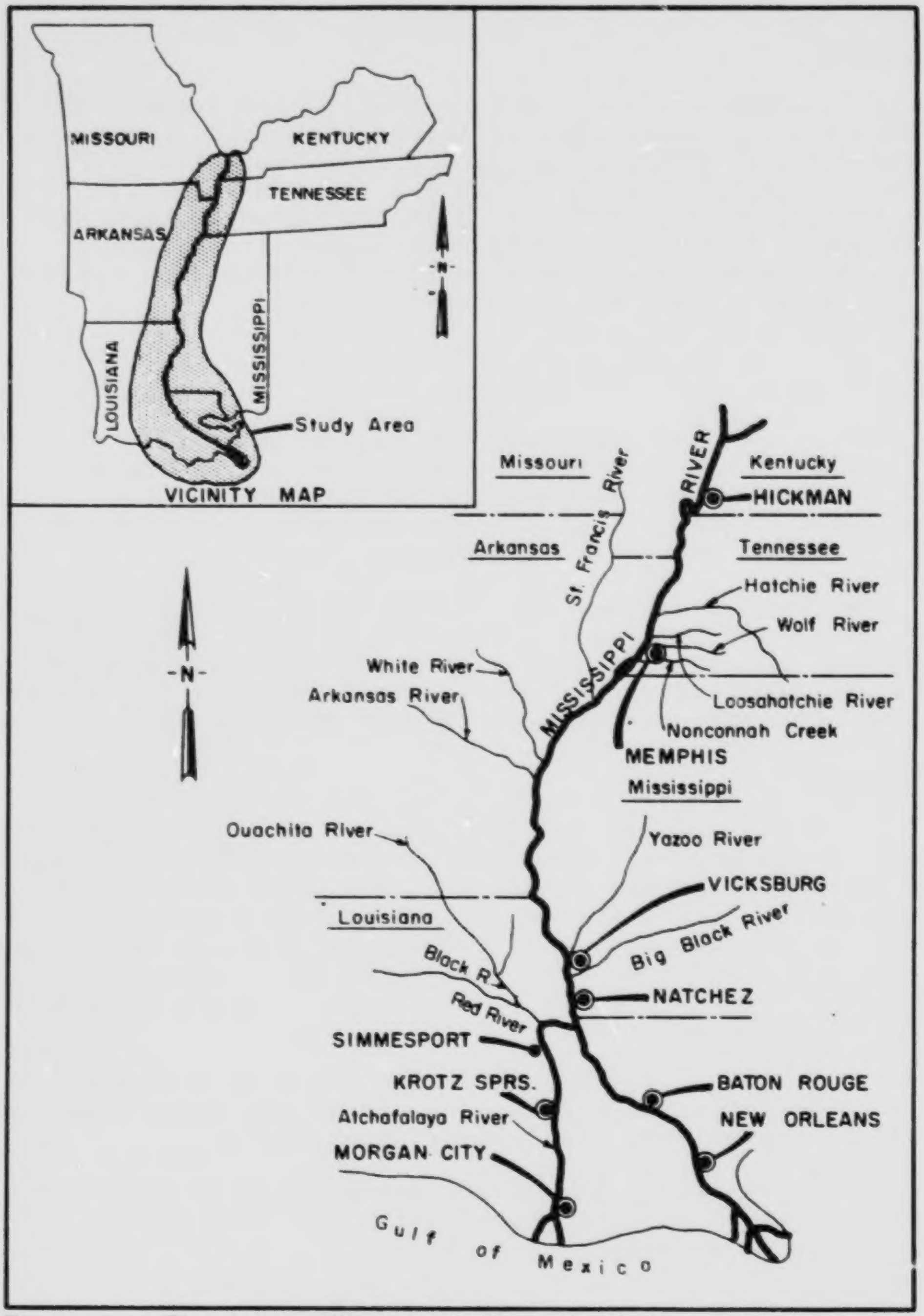
MISSOURI
KENTUCKY
TENNESSEE
ARKANSAS
MISSISSIPPI
LOUISIANA
Study Area
VICINITY MAP
N
Missouri
Kentucky
HICKMAN
RIVER
St. Francis River
Arkansas
Tennessee
Hatchie River
Wolf River
White River
Arkansas River
MISSISSIPPI
Loosahatchie River
Nonconnah Creek
MEMPHIS
Mississippi
Ouachita River
Yazoo River
VICKSBURG
Louisiana
Big Black River
Black R.
NATCHEZ
Red River
SIMMESPORT
KROTZ SPRS.
BATON ROUGE
Atchafalaya River
NEW ORLEANS
MORGAN CITY
Gulf of Mexico

Figure 1 — The Lower Mississippi River Technical Assistance Project study area.

3. To determine the specific origin and means of entry of endrin into surface ground waters;

4. To determine the mechanism which transports endrin through the aquatic environment and food chain into fish and shellfish and concentrates the pollutant to toxic levels;

5. To develop methods for control and prevention of endrin pollution.

Acknowledgements

The cooperation of many persons, municipalities, corporations and agencies is gratefully acknowledged. Special appreciation is expressed to the state water pollution control agencies of Arkansas, Louisiana, Mississippi, and Tennessee; the City of Memphis, State-Federal cooperative agricultural extension services; U. S. Department of the Army; agencies of the U. S. Department of the Interior; the Interagency Coordination Committee; and the Technical Advisory Committee.

SUMMARY OF SIGNIFICANT FINDINGS

1. The solubility of endrin in water is difficult to determine; for the purpose of the study, 260 µg/l was accepted as the "solubility" of endrin in water realizing that all of this was not true molecular solubility.

2. Endrin degrades at a slow but significant rate in cold or warm water under aerobic or anaerobic conditions.

3. Endrin is toxic to certain species of non-resistant fish (e.g. fat head minnow and channel catfish) in water concentrations of from 0.10 to 0.40 µg/l as determined in field and laboratory tests.

4. Endrin is toxic to certain species of non-resistant fish (e.g. gizzard shad and bigmouth buffalo) where concentrations in the blood reach 0.10 to 0.28 µg/g depending on the species. *

5. Some fish develop a resistance to endrin and can survive with endrin concentration in their blood much higher than concentrations which kill non-resistant fish. Resistant fish were found at times at all sampling stations on the Mississippi and Atchafalaya Rivers.

6. The condition of endrin when it enters an aquatic environment is an important fact in determining its availability to the aquatic biota and, therefore, its potential toxicity to fish.

7. There were two significant sources of endrin in the study area: (1) the waste discharge of the Velsicol Chemical Corporation and (2) agricultural runoff.

8. Process waste discharges of the Velsicol Chemical Corporation were a more significant source of endrin pollution to the Mississippi River prior to November 1966 than thereafter.

* All blood data are reported on a wet weight basis.

9. A study of pesticide formulating plants and raw sugar factories showed that the wastes from these plants were not a significant source of endrin pollution to the Mississippi River.

10. Endrin concentrations in the Lower Mississippi River reached a maximum during the 1964 water year (Oct. 1, 1963 to Sept. 30, 1964).

11. On the average, endrin was relatively uniformly distributed over the length of the Lower Mississippi and Atchafalaya Rivers but was randomly distributed in the cross sections of these rivers.

12. Endrin concentrations in the waters of the estuarine areas of the Mississippi River were of the same magnitude as the water concentrations of the Mississippi River.

13. The production and use of endrin declined after 1964.

14. Mean concentrations of endrin in the blood of fresh water fish declined after March 1966 as compared to most previous sampling periods.

15. Endrin concentrations in the blood of salt water fish taken from the estuarine area of the Mississippi River were of the same magnitude as endrin concentration in the blood of fresh water fish taken from the same river.

16. No endrin caused fish kills occurred in the Mississippi or Atchafalaya Rivers after the fall and winter months of 1963-64.

17. In the tributaries to the Mississippi River, two fish kills occurred in the waters of the Wolf River in 1965 where the endrin in the blood of dead or dying fish exceeded the minimum lethal concentrations. However, in both instances, the dissolved oxygen in the river was zero.

18. A three year fish survey of the Mississippi and Atchafalaya Rivers showed that the fish populations of these two rivers have recovered from any effects of the 1963-64 fish kills except for an apparent paucity of fish in the larger size groups of the more long lived species.

9. A study of pesticide formulating plants and raw sugar factories showed that the wastes from these plants were not a significant source of endrin pollution to the Mississippi River.

10. Endrin concentrations in the Lower Mississippi River reached a maximum during the 1964 water year (Oct. 1, 1963 to Sept. 30, 1964).

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18. A three year fish survey of the Mississippi and Atchafalaya Rivers showed that the fish populations of these two rivers have recovered from any effects of the 1963-64 fish kills except for an apparent paucity of fish in the larger size groups of the more long lived species.

19. A favorable commerical and sport fish population exists in the Mississippi and Atchafalaya Rivers.

20. Endrin was found in oysters taken from the Louisiana estuarine areas but in concentrations reported as insignificant from a public health standpoint.

21. Endrin was found in finished water supplies but in concentrations reported as insignificant from a public health standpoint.

22. The shallow burial of waste endrin at a farm in Hardeman County, Tennessee, has contaminated portions of both the surface and subsurface environment at the disposal site and in Pugh Creek as far as 1 1/2 miles downstream from the site. A substantial portion of the local water-table aquifer, which is the potential source of local domestic water supplies,* is exposed to the hazard of contamination from the water disposal pits.

23. Considerable progress has been made in the reduction of endrin wastes discharged to the Mississippi River from the manufacturing facilities at Memphis, Tennessee.

25. Powdered activated carbon was found to be an effective material for removing endrin from water.

26. Settling for as little as 30 minutes substantially reduced the endrin concentration in the Velsicol Chemical Corporation's process waste waters.

* There are no known domestic water wells in this 150 acre area.

CONCLUSIONS

From information collected prior to and during the course of the study and presented herein, it is concluded that:

1. Endrin was the agent responsible for catastrophic fish kills in the Lower Mississippi River Basin in 1963-64.

2. Wastes from the Memphis, Tennessee, plant of the Velsicol Chemical Corporation and runoff from agricultural lands were the major causes of endrin pollution in the Lower Mississippi River Basin.

3. Endrin formulators and raw sugar factories did not contribute significantly to endrin pollution in the Mississippi and Atchafalaya Rivers, but could pollute groundwaters and local lakes and streams.

4. The Velsicol process waste discharge was a more significant source of endrin pollution in the Mississippi River prior to November 1966 than thereafter.

5. The maximum endrin concentration was present in the Mississippi and Atchafalaya Rivers in 1963-64, a period of maximum production and agricultural use of endrin.

6. Endrin present in the Mississippi and Atchafalaya Rivers, and the rate of production and use, declined after this time to a level where endrin was no longer a pollution hazard.

7. At the present rate and methods of production, waste disposal, and use, concentrations of endrin in the waters of the Lower Mississippi River Basin may be expected to remain at levels not harmful to fish.

8. Education of users and potential users of endrin, other pesticides and toxic, or potentially toxic, materials is needed to minimize losses to receiving waters with the attendant danger of damage to aquatic life.

9. Although the Velsicol Chemical Corporation has made significant progress in reducing endrin losses from

its Memphis plant, the potential still exists for releases that could result in concentrations toxic to aquatic life in the Lower Mississippi River.

10. There is little likelihood that groundwater in the artesian aquifer will be exposed to contamination from the disposal pits in Hardeman County.

11. Endrin contamination of the Memphis, Tennessee, area tributaries including the Wolf, Hatchie and Loosahatchie Rivers and Nonconnah Creek is greater than the contamination in other waterways of the Basin. As late as early 1967, endrin concentrations in the Wolf River especially were dangerous to fish populations and other aquatic life.

12. The existing surveillance network in the Lower Mississippi River Basin should be expanded to include a monitoring program for endrin, other pesticides and toxic materials having a detrimental effect on the waters of the basin together with a periodic fish survey to determine the biological condition of the waterways.

RECOMMENDATIONS

Based on the conclusions, it is recommended that:

1. The Velsicol Chemical Corporation be required to continue their program of reducing the quantities of endrin and other toxic pollutants discharged from their manufacturing plant at Memphis, Tennessee.
2. The base flow of Pugh Creek be sampled at periodic intervals and analyzed for endrin or other chlorinated hydrocarbons in order to determine if the groundwater which feeds the creek has become contaminated.
3. Agricultural use of pesticides in the Lower Mississippi River Basin be oriented toward those compounds that are target effective, less toxic to aquatic life and less persistent in the environment.
4. Legislation be enacted at the Federal level to regulate the manufacture, formulation, distribution and application of pesticides to prevent water pollution, especially the pollution of interstate and coastal waters.
5. The U. S. Department of Agriculture, supported by industry, State and other Federal agencies, increase their educational program for the guidance of the public and pesticide users in the use of pesticides in a manner that will prevent water pollution.
6. The U. S. Department of Agriculture, the agricultural industry, and other Federal agencies conduct studies to devise additional techniques to prevent applied pesticides from reaching waterways.
7. State and local agencies having the authority to limit toxic discharges, take the necessary steps to restrict discharges of pesticides and other toxic materials to the waters of the Lower Mississippi River Basin.
8. Sufficient funds be provided to expand the existing surveillance network program in the Lower Mississippi River Basin. The expanded program should include a

monitoring program for endrin, other pesticides, and toxic materials having a detrimental effect on the waters of the basin. It should further include a periodic fish survey to determine the biological condition of these waterways. This program would help to prevent a recurrence of a major pollution incident such as the one caused by endrin that culminated in the 1963-64 fish kills.

9. State and local agencies having regulatory authority to limit toxic discharges take necessary steps to reduce such pollution to Memphis area tributaries should monitoring data continue to show existing concentrations dangerous to aquatic life.

CHAPTER 1

DESCRIPTION OF STUDY AREA

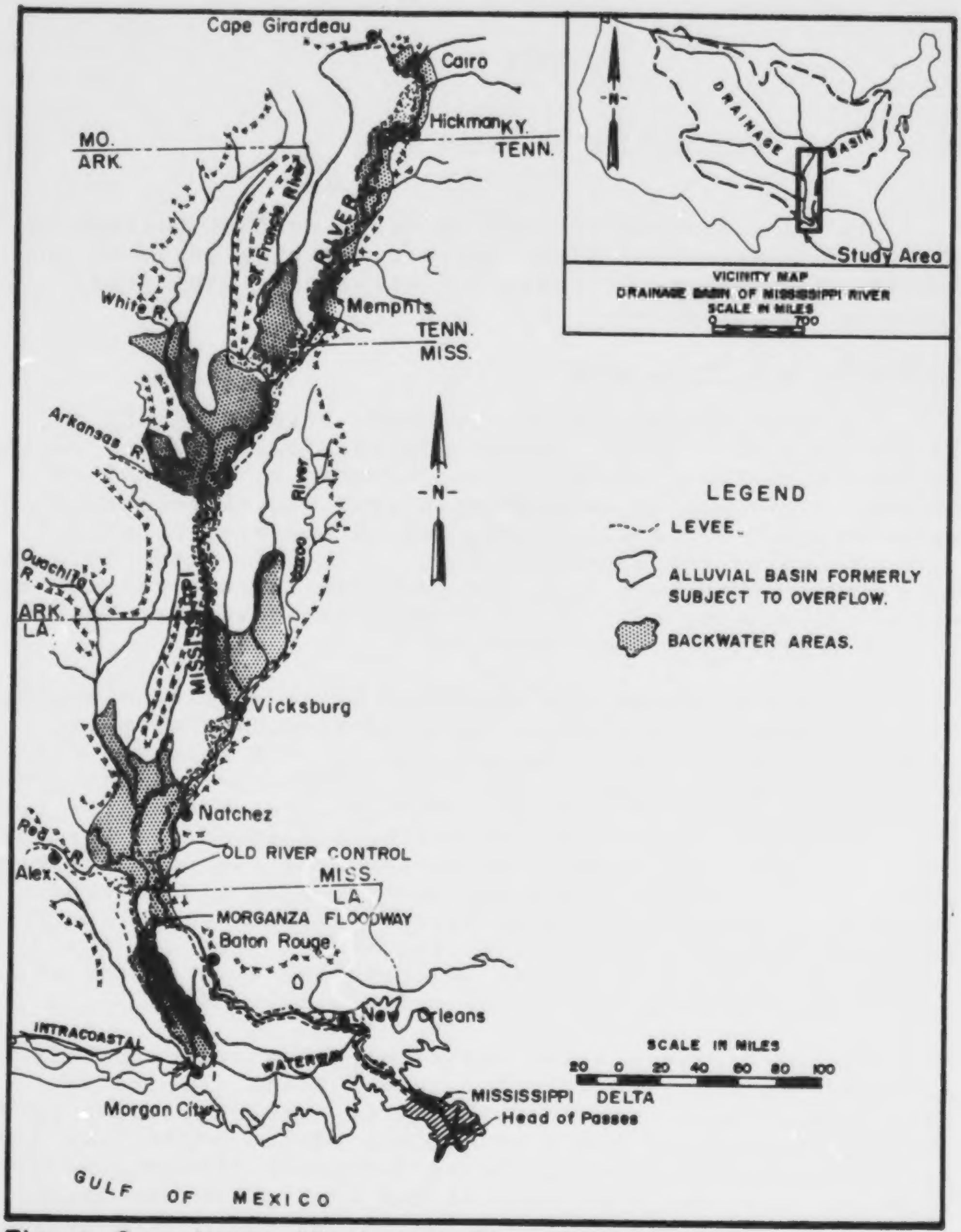
The area covered by this Project was that portion of the Lower Mississippi River Basin comprising parts of the States of Arkansas, Tennessee, Mississippi, Louisiana, Kentucky and Missouri.

Geography and Topography

The alluvial valley of the Lower Mississippi River, (Figure 2), is a broad, gently sloping lowland which begins at Cape Girardeau, Missouri, and extends to the Gulf of Mexico. This valley extends more than 600 miles, varies in width from 30 to 125 miles, and is bordered by abrupt escarpments in the upper reaches. Tributary flows join the main river at various locations and the lowland extends up these tributaries many miles beyond the broad flat basins in the vicinity of the junctions.

The flood plains are dissected by an intricate system of large numbers of shallow lakes of various shapes and sizes, bayous, sloughs, distributaries, and canals. This intricate mosaic of lakes are best illustrated in the lower Atchafalaya Basin (Figure 3). Much of the Mississippi River Basin has been leveed off and has been cleared for agricultural use. The land within the leveed area supports luxuriant growth of herbaceous and woody plants. The higher land supports extensive stands of hardwood timber while land which does not dry out until late in the summer supports thick growths of herbaceous plants interspersed with stands of trees that tolerate considerable flooding.

The Atchafalaya River Basin comprises approximately 1,350 square miles of alluvial bottom lands (Figure 4). This area is noted for its ability to furnish outdoor recreation of many varied kinds and is one of the major fish and wildlife and recreation areas in the Lower Mississippi Basin. It is in this area that some of the most extensive fresh water fish kills occurred. Below Morgan City, located on the lower Atchafalaya River, is 660 square miles of coastal marshlands associated with the River as well as a vast area of associated estuarine and Gulf of Mexico waters.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Yazoo
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ARK.
LA.
MISSISSIPPI
Vicksburg
Natchez
Red R.
Alex.
OLD RIVER CONTROL
MISS.
LA.
MORGANZA FLOODWAY
Baton Rouge
New Orleans
INTRACOASTAL
WATERWAY
Morgan City
MISSISSIPPI DELTA
Head of Passes
GULF OF MEXICO
-N-
LEGEND
LEVEE.
ALLUVIAL BASIN FORMERLY SUBJECT TO OVERFLOW.
BACKWATER AREAS.
SCALE IN MILES
20 0 20 40 60 80 100
DRAINAGE
BASIN
Study Area
VICINITY MAP
DRAINAGE BASIN OF MISSISSIPPI RIVER
SCALE IN MILES
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Figure 2 — Lower Mississippi River Alluvial Basin

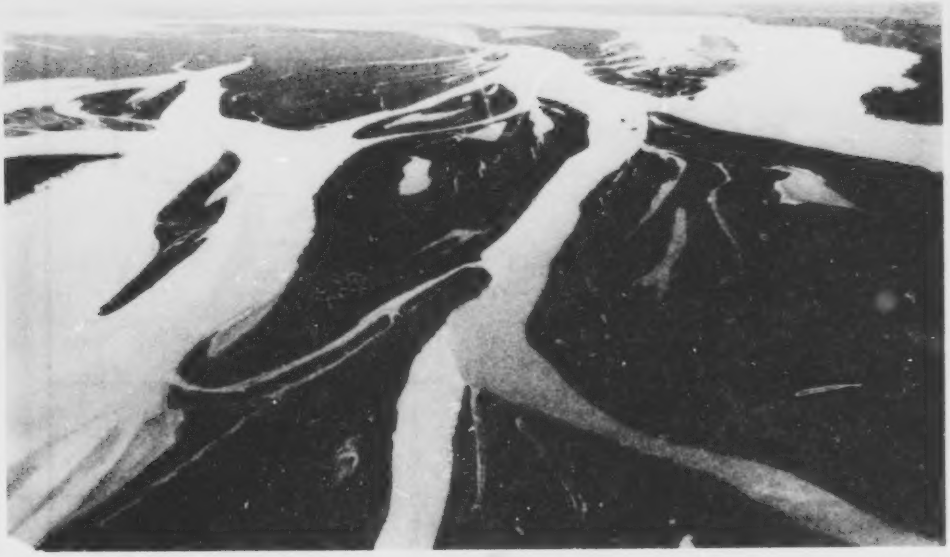


Figure 3 – Lower Atchafalaya Basin showing system of lakes and channels.

The main stem of the Mississippi River is leveed almost to its mouth (Figure 2). Because of the levee system, little of the local drainage below Baton Rouge on the east side and below the Morganza Floodway on the west side of the Mississippi River, as well as local drainage along the Atchafalaya River System, reaches the Mississippi or Atchafalaya Rivers, but is diverted to the estuarine areas. Below the levee system, the Mississippi's present-day active delta contains approximately 470 square miles of marshes. Also associated with this system are vast areas of estuarine and marine waters.

Geology

The Lower Mississippi River Basin is alluvial and was formed during the final cycle of glaciation sequences. During the last glacial stage when sea level was much lower than at

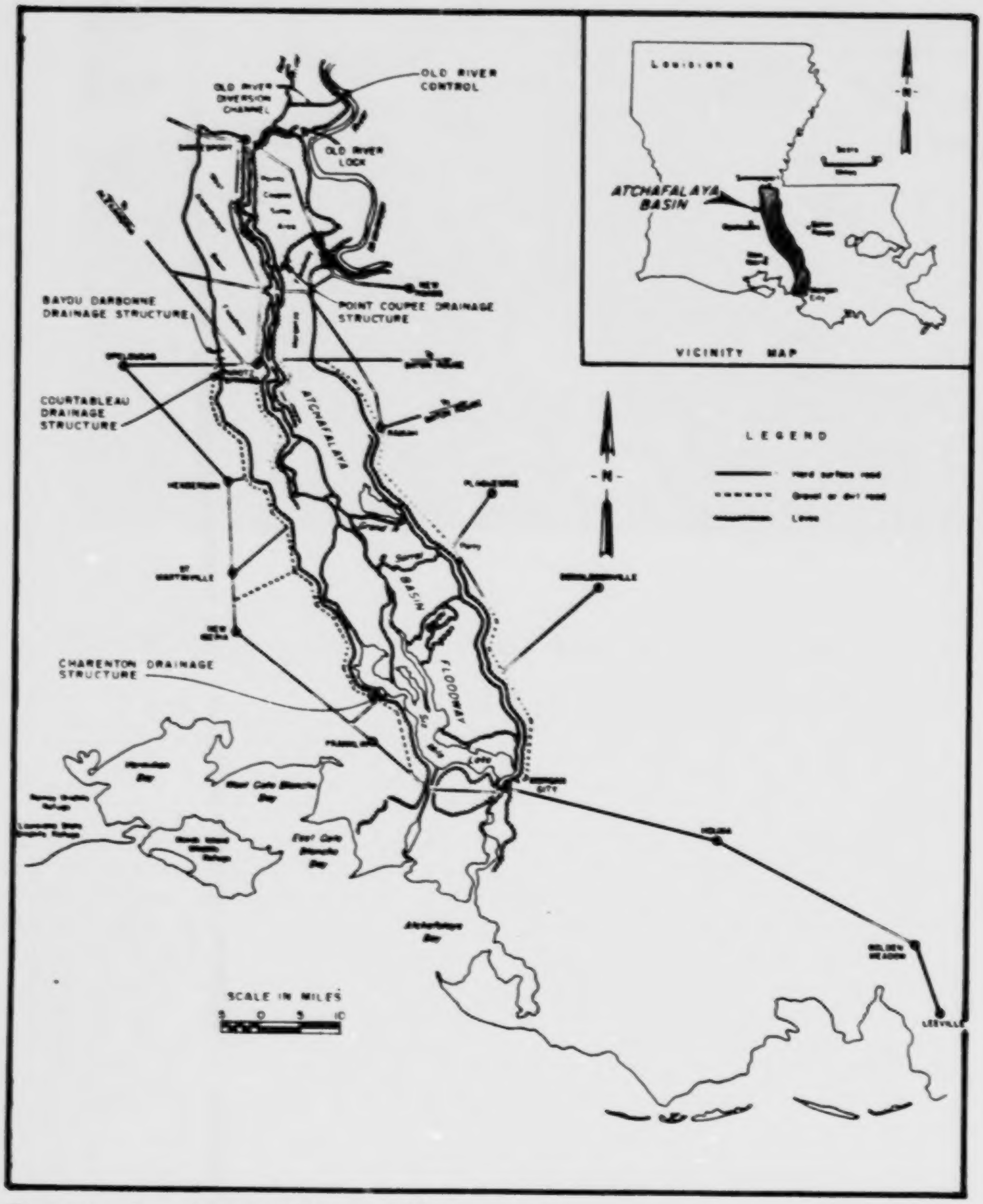

OLD RIVER CONTROL
OLD RIVER DIVERSION CHANNEL
OLD RIVER LOCK
BAYOU DARBONNE DRAINAGE STRUCTURE
POINT COUPEE DRAINAGE STRUCTURE
COURTABLEAU DRAINAGE STRUCTURE
ATCHAFALAYA
BASIN
FLOODWAY
CHARENTON DRAINAGE STRUCTURE
-N-
Louisiana
ATCHAFALAYA BASIN
VICINITY MAP
LEGEND
Hard surface road
Gravel or dirt road
Levee
Vermilion Bay
West Cote Blanche Bay
East Cote Blanche Bay
Atchafalaya Bay
MORGAN CITY
HOUMA
GOLDEN MEADOW
LEEVILLE
SCALE IN MILES
5 0 5 10

Figure 4 — Atchafalaya River Basin

present, the lower valley became deeply eroded and entrenched between the valley's walls. When the glacial ice melted and the sea level rose, the valley filled, the gravels and coarse sand being found generally in the lowest strata. At present the alluvial plain consists primarily of sand and silt, grading progressively to fine sand and silt in the lower portion of the basin with extensive deposits of clay scattered through the sand and silt deposits. A complex soil structure exists in the basin as the lower Mississippi has developed a highly sinuous course, creating meander loops and bends, and has shifted its channel from time to time so that parts of the alluvial plain have been worked and reworked by the river many times. Soils are quite fertile; however, they are easily eroded.

The formation of natural levees of heavy sediments near the stream banks results in drainage away from the stream to low ground near the basin walls. This results in development of bottom land drainage by streams parallel to the main stream and joining it through major tributaries or at points where the main channel meanders close to the basin wall.

Gradual shifting of the Mississippi River in the southern portion of the basin has not occurred. It is only through diversion that the river establishes a new course. The process of development includes the formation of natural levees on both sides of the river and the extension of a delta into the Gulf of Mexico. During some point of this development, the river began to discharge increasing amounts to a distributary. Inasmuch as the distributary is usually a shorter distance to the Gulf of Mexico and the gradient steeper, the percentage of flow in the main channel decreases until the old channel is abandoned. Previous routes of the Mississippi have covered most of south Louisiana.

Presently the Atchafalaya River is the only major distributary of the Mississippi River. Old River which flows out of the Mississippi River joins the Red River to form the Atchafalaya River. The Atchafalaya River was formed during very recent geological times and was a minor drift-chocked stream until about 1900. Since then, developments for navigation and flood control have aided a natural tendency for the river to enlarge and to convey even larger quantities of Mississippi River flow during ordinary and lower water stages.

At the extreme lower portion of the Mississippi River, the river has formed an extensive delta, geologically of very recent origin, jutting into the Gulf of Mexico (Figure 2). There is indication that possibly most of the present-day active delta has been formed since the arrival of Europeans in this country.

Climate

The climate of the project area varies from subhumid to humid. The mean annual precipitation ranges from about 35 to 54 inches. Temperatures in the project area vary from mean lows of 19° to 44°F. in January to mean highs of from 85° to 91°F. in July.

Population and Economic Development

The 1960 population of the project area was approximately 8,000,000. Of this total, urban and rural components were approximately 4,300,000 and 3,700,000 respectively. Cities with over 100,000 population include New Orleans and Baton Rouge, Louisiana; and Memphis, Tennessee.

The Mississippi River is improved for oceangoing navigation to Baton Rouge, Louisiana, and for inland barge navigation connecting with the Gulf Intracoastal Waterway and the improved waterways of the Missouri, Upper Mississippi, Illinois, and Ohio Rivers.

Agriculture is a major occupation in a large portion of the project area. However, the labor supply released by mechanized agriculture, the availability of adequate plant sites with good water supplies, access to raw materials and a good transportation system have attracted a highly diversified manufacturing industry which uses water from the Mississippi River extensively. This use is expected to continue to grow rapidly. Notable among the manufacturing industries along the Mississippi River are the petrochemical complex at Baton Rouge and the agricultural chemicals manufacture at Memphis, Tennessee. The Mississippi River and its tributaries are used as a water source by approximately 1.8 million people in the study area. Commercial and sport fishing is of major economic importance in the project area, especially in the lower portion of the Mississippi River Basin. For example, Louisiana leads the nation in commercial fishery landings and in the value of these products.

Hydrology

Historically, the tributary basins and lowlands along the main river have been subject to annual flooding; however, the construction of levee systems has greatly reduced the area subject to flooding. In 1879 the Mississippi River Commission was organized and under its direction a unified levee system along the entire extent of the Lower Mississippi Valley began to grow and is now essentially complete, except for the main backwater areas in the vicinity of the St. Francis, White, Arkansas, Yazoo, Red, and Atchafalaya River Basins. (Figure 2).

The Red River backwater area in Louisiana comprises about 2,650 square miles of flat lowlands in a natural storage basin at the junction of the Red and Mississippi Rivers. This area is subject to overflow by the Red River, and by flow escaping from the main stem of the Mississippi River through the Old River Control Structure in the west main levee. Both low water and flood flows through the backwater area drain to the Gulf of Mexico through the Atchafalaya River and Floodway. Because of the construction of levees, the Atchafalaya River Basin north of Krotz Springs does not annually overflow; however, the 878 square mile portion of the basin between Krotz Springs and Morgan City annually overflows. A system of interlocking levees encompass the Atchafalaya River Basin. The Atchafalaya River has enlarged itself to such an extent since 1900, that some 30 percent of the total annual Mississippi River flows is now diverted down the river; however, a control structure put in place in 1963 prevents further increases in diversion of Mississippi River flows.

Discharges in the Mississippi River Basin, taken from surface water records published by the U. S. Geological Survey, are shown in Figure 5. Unfortunately, the periods of record vary from station to station; however, they do illustrate the large volumes of water, even during low flow periods, which required consideration during the study.

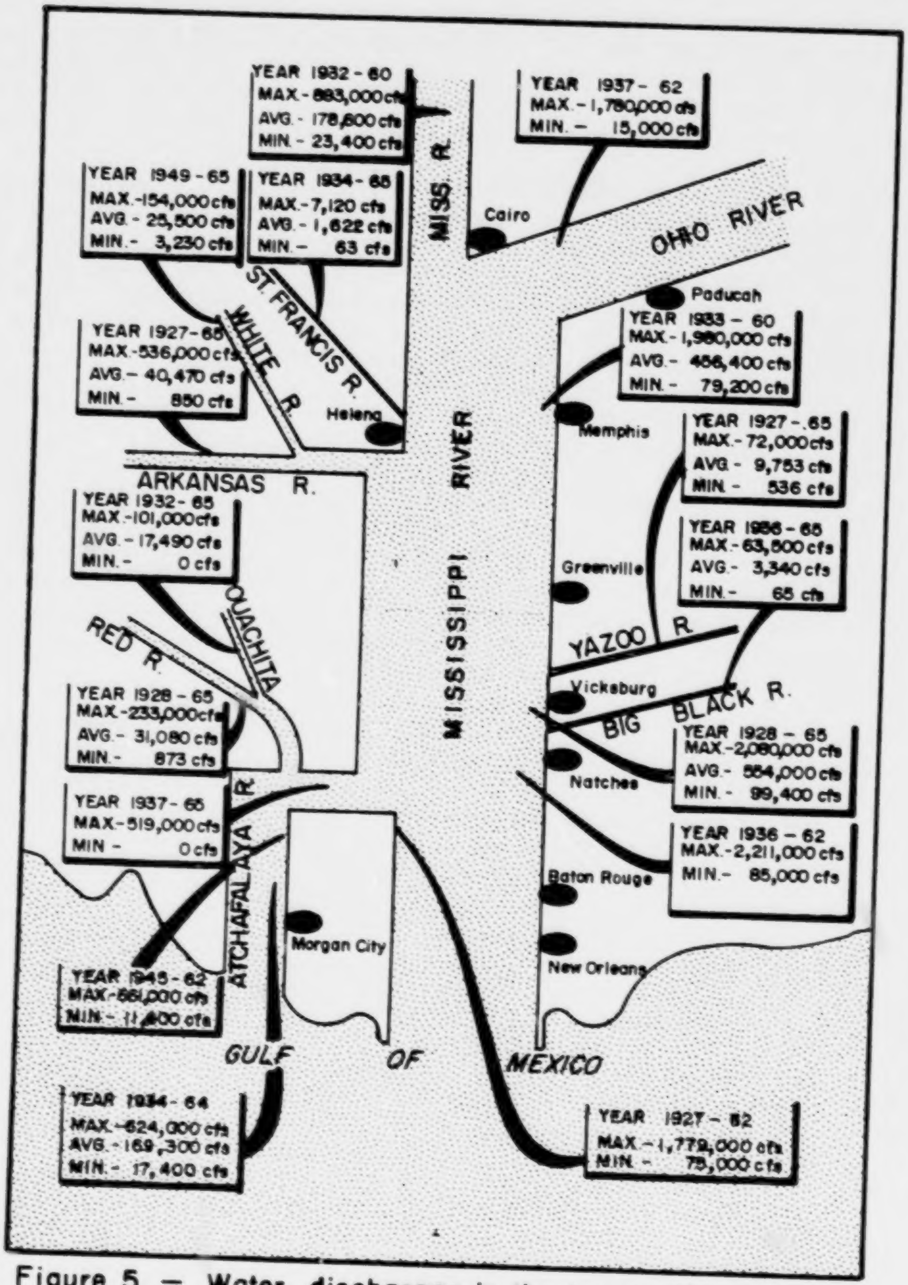

YEAR 1932 - 60
MAX. - 883,000 cfs
AVG. - 178,800 cfs
MIN. - 23,400 cfs
YEAR 1937 - 62
MAX. - 1,780,000 cfs
MIN. - 15,000 cfs
YEAR 1949 - 65
MAX. -154,000 cfs
AVG. - 25,500 cfs
MIN. - 3,230 cfs
YEAR 1934 - 65
MAX. - 7,120 cfs
AVG. - 1,622 cfs
MIN. - 63 cfs
MISS. R.
Cairo
OHIO RIVER
Paducah
ST. FRANCIS R.
WHITE R.
YEAR 1927 - 65
MAX. - 536,000 cfs
AVG. - 40,470 cfs
MIN. - 850 cfs
YEAR 1933 - 60
MAX. - 1,980,000 cfs
AVG. - 486,400 cfs
MIN. - 79,200 cfs
Helena
Memphis
ARKANSAS R.
MISSISSIPPI RIVER
YEAR 1927 - 65
MAX. - 72,000 cfs
AVG. - 9,753 cfs
MIN. - 536 cfs
YEAR 1932 - 65
MAX. -101,000 cfs
AVG. - 17,490 cfs
MIN. - 0 cfs
YEAR 1936 - 65
MAX. - 63,800 cfs
AVG. - 3,340 cfs
MIN. - 65 cfs
Greenville
OUACHITA
RED R.
YAZOO R.
Vicksburg
BIG BLACK R.
YEAR 1928 - 65
MAX. - 233,000 cfs
AVG. - 31,080 cfs
MIN. - 873 cfs
YEAR 1928 - 65
MAX. - 2,080,000 cfs
AVG. - 554,000 cfs
MIN. - 99,400 cfs
Natches
YEAR 1937 - 65
MAX. - 519,000 cfs
MIN - 0 cfs
ATCHAFALAYA R.
YEAR 1936 - 62
MAX. - 2,211,000 cfs
MIN. - 85,000 cfs
Baton Rouge
Morgan City
New Orleans
YEAR 1945 - 62
MAX. - 661,000 cfs
MIN. - 11,800 cfs
GULF OF MEXICO
YEAR 1934 - 64
MAX. - 624,000 cfs
AVG. - 169,300 cfs
MIN. - 17,400 cfs
YEAR 1927 - 62
MAX. - 1,779,000 cfs
MIN. - 75,000 cfs

Figure 5 — Water discharges in the Lower Mississippi River Basin.

CHAPTER 2

ENDRIN PROPERTIES

Introduction

Endrin belongs to a group of chemicals that are highly chlorinated cyclic hydrocarbons with characteristic "endomethylene bridges" structures. Physical properties of endrin are summarized in Table 1.

Aqueous Solubility

Much of the older literature states that endrin as well as chlorinated hydrocarbons in general, is insoluble in water. Chlorinated hydrocarbons do not ionize and the molecules are quite non-polar in contrast with the polar configuration of water molecules. With the development of methods with greater analytical sensitivity and with new interest developed in the occurrence of endrin in the aqueous environment, some values for solubility have appeared in the literature.

Perhaps the most accurate solubility determination of a chlorinated hydrocarbon was performed by Bowman, Acree, and Corbett (1) with carbon-14 DDT. They state that for substances as insoluble as DDT, minute undissolved particles which are formed during the preparation of saturated aqueous solutions do not aggregate readily; therefore, use of conventional methods for solubility determinations such as filtration or mild centrifugation fails to remove all suspended particles and gives higher values. Thus, the more conventional determinations of solubility of endrin do not measure true solubility, i.e., molecularly homogeneous mixture in water, but measure amounts of endrin in distilled water in at least three forms: 1. molecularly dispersed, 2. adsorbed on suspended material and 3. molecularly aggregated in various sizes. Thus, the term "solubility" in this report will be used to include the various types of mixtures defined above and will not refer to true solubility.

Richardson, L. T. and Miller, D. M. report that the solubility in water is 230, 380, and 510 µg/l at 25°, 35°, and 45°C., respectively (2). Work has shown that the solubility of non-polar compounds like endrin is variable

Table 1. Summary of physical properties of endrin.

Property	Description
Empirical formula	$C_{12}H_8OCl_6$
Molecular weight	380.76
Flammability	Nonflammable
Corrosive action	Noncorrosive
Physical state at 68°F.	flowable crystals
Color	off-white to light tan
Odor	mild chemical
Insolubility residue percent weight	less than 0.5 in xylene
Density	1.75
Vapor pressure, mm Hg at 77°F.	2x10
Setting point °F.	rearranges when heated above 390°F.
Bulk density lb/cu ft.	55-60
Endrin content percent weight minimum (technical grade)	95
Chlorine content	55-57
Free acid percent weight	less than 0.4, calc. as acetic acid
Solubility at 77°F.	
Xylene	3.3 lb/gal (approx.)
Aliphatic hydrocarbons	low, about 0.1 lb/gal
Methyl alcohol	sparingly
Water	relatively insoluble

Note: Analytical Procedures for Endrin may be found in the Appendix, Exhibit B.

since the individual molecules tend to aggregate to form a range of particle sizes, hence the solubility value will depend on the size of endrin particle remaining in suspension after some arbitrary pretreatment to remove gross-sized particles. The Project adopted the following criteria for the solubility of endrin in water; solubility in a suspension containing particles no greater than 5 microns (obtained by filtration through a fritted glass filter), and solubility in a suspension containing particles no greater than approximately 0.05 microns (obtained by centrifugation at 34,500G). The following values for aqueous solubility at approximately 25°C. for endrin were found: 1. 260 µg/l for particles no greater than 5 microns, and 2. 190 µg/l for particles no greater than .05 micron.

An additional experiment was performed by the Project to determine the approximate maximum aqueous solubility regardless of the size of endrin particles remaining in suspension after allowing time for the material to settle.

A five-gallon wide mouth carboy was equipped with a teflon lid and liner. Two holes were made in the lid to accommodate a mechanical stirrer and a volumetric pipette. The carboy was filled to the 16,000 ml level with distilled water. One gram of endrin (99.3 percent pure) was added to the water and the mixture was thoroughly stirred for a period of twenty minutes. The solution was allowed to stand at 21°C. (± 1°) for 18.5 hours to allow all particulate matter to drop below a one cm. sampling level. The settling was necessary so that the possibility of sampling particulate matter would be remote. The pipette opening was plugged at all times other than sampling time.

The first three samples were siphoned from the carboy with a 10 ml pipette after an 18.5 hour settling time. Series of three samples were taken at intervals, which were various multiples of 24 hours. The mixture was thoroughly stirred after each series of samples was taken. Figure 6 shows the concentrations of endrin in the samples. As with the previous experiments, solubility appeared to level off at approximately 260 µg/l, therefore for the purpose of this study, 260 µg/l was accepted as the "solubility" of endrin in water, realizing that all of this is not true molecular solubility.

Chemical Reactions and Stability

A substantial amount of work has been done on the organic chemistry of endrin but this report is not considered to be the place for a detailed discussion of this aspect. For this information, however, a good reference, plus the bibliography it contains, is the paper by Soloway et al. (3). One reaction, however, is pertinent to the discussion here, and that is the molecular rearrangement that endrin undergoes under both thermal and acid-catalyzed conditions. Also, Rosen et al. (4) have pointed out that endrin is rapidly decomposed by ultraviolet light.

Thermal stability of endrin is important during analysis by gas chromatography where endrin is subjected to temperatures of about 200°C.

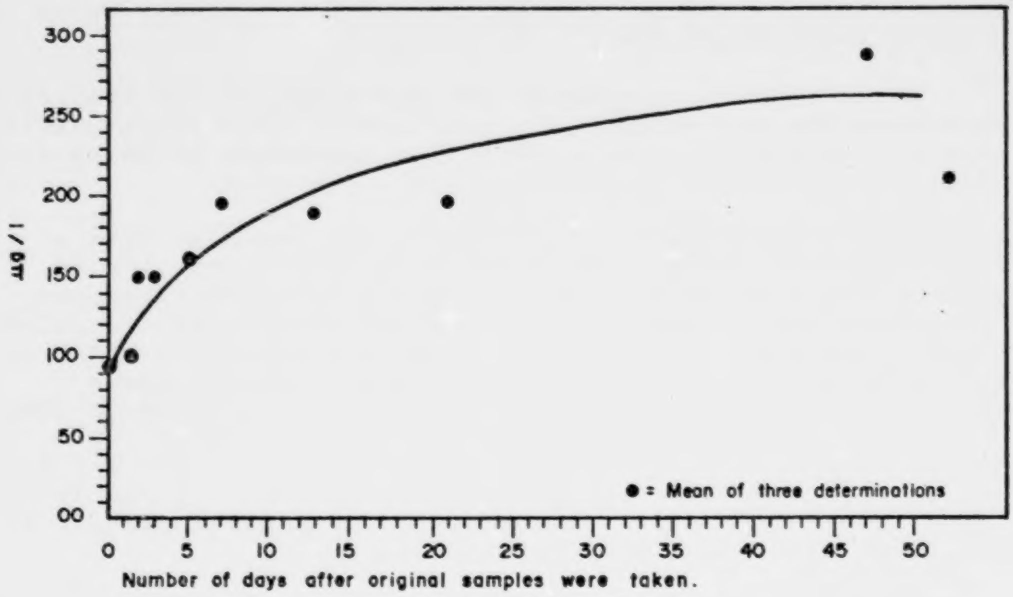


Figure 6 — Concentrations of endrin in distilled water after settling. Curve was fitted by inspection.

Natural Degradability in Water and Water Bottoms

Biodegradation of pesticides occurs under both aerobic and anaerobic conditions, but Hill (5) states that enzyme studies suggest that different enzymes for degrading chlorinated hydrocarbons are operable under the two conditions. He further states: "Anaerobic enzymes will not function under aerobic conditions, and vice versa. It appears that reduced cofactors, in conjunction with necessary enzymes are the key to anaerobic degradation and they would be expected only under anaerobic conditions."

Inasmuch as pesticides, especially those which can function as co-enzymes, are not inert, they can be expected to adsorb on organic matter. Normally adsorption on organic matter is largely irreversible and is usually considered chemical adsorption and could result in large organic complexes that could last indefinitely. These organic complexes could settle out and form organic bottom sludges or, as Hill (5) states it, "a functional pesticide sink". The backwater lakes, and even temporary overflow land along the Mississippi and Atchafalaya River and especially the intricate system of large numbers of shallow lakes of various shapes and sizes, bayous, sloughs, distributaries and canals in the Atchafalaya Basin offer considerable opportunities for the formation of organic bottom deposits.

As Hill points out: "particulate matter tends to settle in a still body of water; and where the particulate matter contains a fair amount of organic material the bottom will be not only anaerobic but quite biologically active". Thus, there could be considerable settling and concentration of endrin in water bottoms and it would be of value to know if endrin would degrade, biologically or otherwise under these conditions.

Hill (5) and Hill and McCarty (6) found considerable reduction in the amount of endrin and apparent degradation products of endrin in both poisoned (with mercurous chloride) and biologically active mixtures of thick organic anaerobic sludges at 35°C. in less than 30 days. Even though it was not clear if this was biological or chemical degradation, it is apparent that under such conditions endrin will degrade. However, as Hill and McCarty (6) point out, this environment of thick organic sludge was chosen to obtain indications of degradation which would probably occur only slowly in less favorable, natural environments.

An experiment was conducted to determine the biodegradability of endrin in a stratified aqueous environment in the laboratory. From this experiment it was concluded that endrin will degrade at a slow but significant rate in cold or warm water under aerobic or anaerobic conditions. Details of the experiment are found in the Appendix, Exhibit C.

Persistence in Soils

Data on the persistence of endrin in soils are limited. There is available a summary of the experimental work done on the behavior and disappearance of endrin in soils listing 31 references (7). The conclusions presented can best be summarized by repeating verbatim the conclusions of the report. Thus:

> "From all the preceding information, it is concluded that the chlorinated hydrocarbon insecticides, aldrin, dieldrin, and endrin do not accumulate in the soil. When they are applied in consecutive years at practical dosages, enough of the previous treatments have dissipated

so that the new application does not result in increased concentrations. Analyses show that as soon as treatments to the soil stop the residues of most chlorinated hydrocarbon insecticides dissipate at the rate of approximately 30 percent per year.

"Although the main portion of the insecticide applied disappears from the soil, the dissipation rate and the specific amount of dissipation depend on six primary factors: soil type, soil temperature, soil moisture, soil microorganisms, application rate and soil cultivation.

"It is indicated that water causes a deactivation of the soil particles which enhances the vaporization rate. Once this is accomplished by irrigation or rainfall, a major part of the insecticide is lost to the atmosphere by this volatilization process and is further degraded by ultraviolet light when exposed to the atmosphere.

"It is concluded that under normal agricultural practices aldrin, dieldrin or endrin are not transported by water within the soil. It has been shown that (1) they move upwards in the soil and are located in the upper two-inch layer even after having been worked into soils to a depth of five inches; (2) they are degraded by microbiological activities and ultraviolet light and are volatilized at the soil-air interface when displaced by water; (3) water cultivation reduces the residue level, but they are not leached into the local water courses largely because of their insolubility; (4) no accumulation of these insecticides would occur in soils under normal agricultural practices."

Anderson (8) in his studies on the fate of aldrin, dieldrin, and endrin, applied to soils, has provided some of the evidence to show that these compounds do not accumulate indefinitely in soil as the result of yearly applications. At some point in time, the rate of disappearance of the compound equals the application rate, and the concentration residing in the soil remains rather constant. When pesticide application is stopped, the pesticide residue in the soil decreases. Figure 7 taken from Anderson's report, shows this behavior for endrin. During the years 1954 to 1958, yearly application of 5 lb/acre disced to 6 inches into the soil resulted in a maximum residual endrin in the soil of about 4000 µg/kg decreasing to about 3500 µg/kg by 1958. When application of endrin was stopped following 1958, the residual endrin decreased to about 1700 µg/kg by 1961.

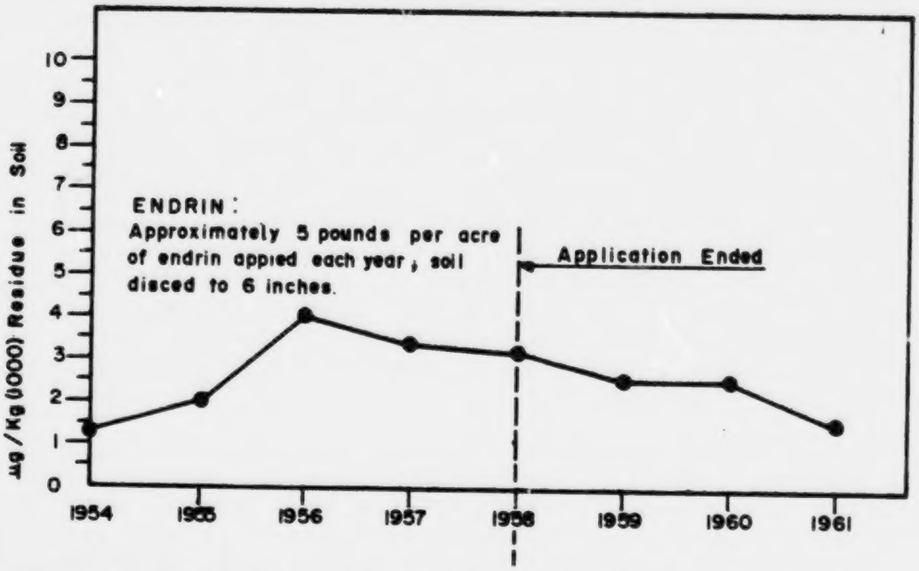


Figure 7 — Residue of endrin in soil from Imperial Valley Plots, from Anderson (8).

Foster, et al. (9) found in the fall of the year at Beltsville, Maryland that 100 percent of the accumulative amount of endrin applied yearly to soil remained after two years and 78 percent remained after three years. They also found 45 percent of the endrin applied in 1952 remaining in the fall of the year and 25 percent of the accumulative amount applied over a two year period remained in the soils in the fall of the year at State College, Mississippi. Furthermore, they found 32 percent of the accumulative amount of endrin applied to soils over a five year period still remaining at New Brunswick, New Jersey. Foster, et al., in their studies, concluded that endrin tends to accumulate in soils to the same degree as DDT and that DDT is so persistent as to present a definite hazard as a soil residue to growth of some crops under some conditions. Lauer et al. (10) found that in the Bayou Yokely area of Louisiana endrin residues persist from one annual treatment season to the next in sugarcane fields while Oatman (11) reported that endrin applied as spray to soils at the rate of 2.5 lbs. toxicant per acre continued to provide effective control of the apple maggot with a 94.1 percent reduction five years (1958-1962) after application in Wisconsin.

Nash and Woolson (12) measured 41 percent of endrin still remaining in Congaree sandy loam soil plots at Beltsville, Maryland after being applied at the rate of "100 and 25 ppm" 14 years previously. According to Nash and Woolson, treatment and maintenance of the soil plots were such that leaching, volatilization, photodecomposition, mechanical removal, and probably biological decomposition were at a minimum. They found that the disappearance of endrin was arithmetic rather than a geometric, linear function of time, such as they found for other pesticides.

Even though the quantities of endrin in soils from applications from one year to the next are not strictly additive, it is concluded that they do accumulate until an equilibrium is reached between disappearance and application and that when endrin application is stopped, significant amounts of endrin will still be present in soils for many years.

Relationship of Endrin to Suspended Sediments in River Water

A comparison of endrin concentration and weight of suspended sediments in representative samples of Mississippi River water was made. Results suggested that endrin concentrations have little relationship to the weight of suspended sediments of a size to be present in the nonfilterable residue in river water. Details of the experiment resulting in this finding may be found in the Appendix, Exhibit D.

Discussion

The true, molecular solubility of endrin in water is difficult to determine. Published data and data presented here on the solubility of endrin includes endrin in water in three forms: 1. molecularly dispersed, 2. adsorbed on suspended material and 3. molecularly aggregated in various sizes. For the purpose of this study 260 µg/l will be accepted as the solubility of endrin in water realizing that all of this is not true solubility. Endrin is unstable due to its particular stereo-chemical configuration, and readily undergoes molecular rearrangement in the presence of heat, ultraviolet light, and acids. This property requires the addition of stabilizing agents in commercial endrin formulations, limits its storage life, and requires a careful control of conditions during gas chromatographic analyses. Endrin degrades at a slow but significant rate in cold or warm water, under aerobic or anaerobic conditions, and in the absence and presence of microorganisms. There was little relationship to the amount of suspended sediments measured in river water and endrin concentrations, and considering the solubility of endrin in water and the range of endrin concentration encountered in river water, it is possible for endrin to be unrelated to other particulate matter in river water.

CHAPTER 3

TOXICITY OF ENDRIN

The hazards of pesticides to man and his environment have been of much concern and a hotly debated subject, especially during the last few years. There is realistic concern over the detrimental effects of chlorinated hydrocarbon pesticides, as several of these pesticides have been shown to be acutely toxic to animals in the very low parts-per-billion range. Endrin is considered by most authorities, e.g., Henderson et al. (13), to be one of the most toxic of all chemicals to fish.

Toxicity of Endrin to Fish

A review of published toxicity values of endrin to fish shows that endrin is extremely toxic to many different species. (Details in Appendix, Exhibit E.) The TL_m values (the concentration at which fifty percent of the test fish survive during the time interval specified), based on flow-through bioassay tests, are generally less than one µg/l. As would be expected, toxicity levels based on static tests are more variable (Exhibit E); however, these levels are for the most part also extremely low. Some of the higher values reported are for resistant strains of fish, e.g. those reported by Ferguson and co-workers (14, 15, 16, 17). The project made no effort to determine species sensitivity ranges of endrin in water; but as a by-product of studies to determine relationship between endrin concentrations in the bloods of gizzard shad and acute toxicity, some reasonably good estimates were obtained of the minimum lethal concentrations of endrin in water for several different species of fish (Table 2). These results are based on flow-through tests and measured concentrations of endrin in the water.

Critical levels indicative of acute intoxication from endrin in fish blood were found to range from 0.23 to 0.28 µg/g for channel catfish and from 0.10 to 0.14 µg/g for gizzard shad. Details of studies to determine endrin concentrations in blood of fish may be found in Exhibit F in the Appendix.

Note: µg/g = 1000 µg/l, wet weight assuming sp. gr. of 1.0.

Table 2. Minimum lethal concentrations of endrin in water to certain species of fish.

Common and scientific names of fishes	Concentrations of endrin in µg/l
Fathead minnow, *Pimephales promelas*	.25 - .40
Channel catfish, *Ictalurus puntatus*	.25 - .30
Brown bullhead, *Ictalurus platycepralus*	.10 - .20
Gizzard shad, *Dorosoma cepedianum*	.10 - .20
Bigmouth buffalo, *Ictiobus cyrinellus*	.10 - .15

Influence of Suspended Solids

The most frequent attempts to understand the relationship between suspended solids and aquatic life have considered the direct deleterious effects of these solids on the organisms. Such consideration is important and necessary in the study of water quality requirements, but it does not determine whether turbidity needs to be considered when it occurs at concentrations that are not in themselves directly adverse. Most studies concerned with the toxicity of soluble materials to aquatic organisms, especially fish, have been conducted with experimental waters that usually contain little or no suspended solids. Exceptions to this are studies on the effect of suspended solids on black fly control with DDT (18), and rotenone toxicity to fathead minnows (*Pimephales promelas*) (19). Ferguson et al. (20) conducted static fish-toxicity tests after adding endrin to a turbid water. They also determined that several chlorinated hydrocarbons adsorbed on bottom sediments as a result of runoff from cotton fields were not released in lethal amounts into standing water.

An experiment was carried out to determine the effects of natural levels of suspended solids on the toxicity of endrin to fish. The results of this experiment and that of Ferguson et al. (20) indicate that the condition of endrin, whether adsorbed on particulant matter or not, when it enters an aquatic environment is an important factor in determining its availability and, therefore, its potential toxicity to fish. The work of Ferguson et al. (20) indicates that only a small percentage of endrin associated with bottom sediments becomes available to fish in a short time. Details of an experiment to determine the effects of suspended solids on the toxicity of endrin to fish are shown in Exhibit G in the Appendix.

Resistant Fish

Boyd and Ferguson (21), Ferguson (22), Ferguson et al. (15), and Ferguson and Bingham (16) demonstrated that certain populations of mosquitofish, golden shiners (Notemigonus crysoleucas) green sunfish, yellow bullhead (Ictalurus natalis), and bluegill from near heavily sprayed cotton fields in the Delta area of Mississippi are resistant to endrin. To determine endrin resistance in fish, about 300 live bluegill and green sunfish were collected near Indianola, Mississippi and exposed to various concentrations of endrin in a series of survival tests and blood concentration tests. Results indicated that: (1) Survivals of the bluegill and green sunfish were erratic; (2) some fish could survive (50-60 percent) endrin concentrations in water as high as 100 μg/l, whereas the control fish (Ohio bluegill) died at endrin concentrations of 0.25-0.5 μg/l; (3) high blood concentrations of endrin do exist in the Mississippi fish and that these fish are tolerant and alive after three days with as much as 41 μg/g endrin in their blood; and (4) the Ohio fish died sooner (14 hours) and at lower blood concentrations (0.78 μg/g) although exposed to the same water concentrations of endrin. These results indicate that the Mississippi fish blood levels were high because the fish accepted endrin into their blood and could tolerate it.

Another group of endrin resistant bluegill from Mississippi was studied to determine the amount of endrin that might accumulate in fish muscle tissue as a result of controlled exposures. Preliminary data showed that compared with the water concentration there is approximately a thousandfold concentration factor of endrin in muscle tissue of these resistant fish.

Ferguson (14) concluded in his study of resistant and susceptible strains of mosquitofish: "that the mechanism of resistance is physiological toleration of massive endrin accumulations ..."

Effects of Temperature

Katz and Chadwick (23) reported that temperature had a marked influence on toxicity of endrin to bluegills, the toxicity increasing with the rise of temperature. Iyatomi et al. (24) working with carp (*Cyprinus carpio*) noted the same effect, while Cope (25) found the same effect working with bluegill and rainbow trout (*Salmo gairdneri*).

CHAPTER 4

SOURCES OF ENDRIN POLLUTION

Manufacturers

Introduction. There are two manufacturers of endrin in the United States. One, the Shell Chemical Corporation, Agricultural Chemicals Division, located near Denver, Colorado, disposes of endrin wastes by deep well injection. The other, the Velsicol Chemical Corporation endrin manufacturing facility located six miles east of the Mississippi River in the central section of Memphis, Tennessee, was the only endrin manufacturer discharging partially treated process wastes into the Mississippi River or its tributaries.

Investigations conducted by the Division of Water Supply and Pollution Control, U. S. Public Health Service, during the spring and summer of 1964 in Memphis and reported at the conference held at New Orleans in May 1964 (26) revealed that:

1. Process wastes from the Velsicol Chemical Corporation manufacturing plant are discharged through a 36-inch sewer into a 48-inch Memphis sanitary sewer which is connected to a 96-inch interceptor sewer discharging untreated sewage into the Mississippi River. The interceptor sewer is known as the Wolf River Interceptor. Prior to June 1963, the process wastes were discharged through a 24-inch sewer into Cypress Creek, a tributary of the Wolf River.

2. Sanitary wastes from the Velsicol manufacturing plant are discharged through an 8-inch line connected to a 33-inch city sanitary sewer running parallel to the western boundary at the plant property. Sewage, from the 33-inch sewer and the 48-inch sewer into which the process wastes are discharged, flows to the Fairfax Bayou pumping station. During high stages on the Mississippi, the station is used to pump sewage into the Wolf River interceptor at a point approximately 5.6 miles from the Mississippi River.

3. Cooling water from the Velsicol Chemical Corporation manufacturing plant is discharged into Cypress Creek through the old 24-inch process waste water sewer. Cypress Creek is concrete lined to Meagher Street; from Meagher Street to its termination with the Wolf River, the creek flows in a natural earthen bed.

4. Endrin concentrations as high as 1,270 µg/l were found in the waters of the sanitary sewer system which receives Velsicol wastes; endrin concentrations as high as 233 µg/l were found in the waters of the natural drainage systems which directly or indirectly receive Velsicol wastes.

5. Endrin concentrations as high as 4,600,000 µg/l were found in sludges or muds which had accumulated in the bottom of Cypress Creek below Velsicol cooling water discharge.

6. A Memphis municipal dump at Hollywood Street near Wolf River was used by the Velsicol Chemical Corporation for the disposal of solid and semi-solid pesticide manufacturing wastes and for the disposal of the sludge removed from the concrete lined portion of Cypress Creek.

Further investigations in late September and early October, 1964 found endrin concentrations as high as 20,040,000 µg/l in sewage sludge accumulations in 3400 feet of the Wolf River interceptor. In September 1964, the Velsicol Chemical Corporation discontinued using Hollywood Dump and purchased a farm in Hardeman County, Tennessee for the disposal of solid and semi-solid wastes from their pesticide manufacturing. Because of the previous findings and happenings, the following actions resulted:

1. On January 22, 1965 the Memphis City Public Works Department and the Memphis-Shelby County Health Department bypassed the 3400 foot endrin laden section of the interceptor into Wolf River. Between October 8 and December 22, 1965, the endrin laden sludge was removed, and the interceptor reopened on December 23, 1965.

2. In May 1966, the City of Memphis let bids and started construction on paving the earthen channel section of Cypress Creek below Meagher Street to University Street. Plans have been prepared and right-of-way is being obtained to pave the section from University to Evergreen Street.

3. In the fall of 1965, the Velsicol Chemical Corporation installed an incinerator to dispose of part of their solid and semi-solid wastes and a vacuum filter for removing solids from the process waste water.

4. In May 1966, the U. S. Geological Survey, under contract with the FWPCA, initiated a ground water pesticide study near Velsicol's Hardeman County, Tennessee solid and semi-solid pesticide waste burial site.

Sampling Methods. Sampling stations were established on the processing, cooling and sanitary waste water discharge lines from the Velsicol Chemical Corporation and on the Memphis City sewers receiving the process wastes (Figure 8 and Table 3).

Generally, grab samples from all sampling stations were collected five times weekly from January 18, 1965 to April 26, 1966; however, sampling of sanitary waste water discharges was not initiated until July 13, 1965. After April 26, sampling of only the Velsicol process waste and cooling water discharges was continued. The process waste water continued to be sampled approximately five times weekly while occasional night and weekend samples were collected throughout the reporting period. Cooling water discharges were generally sampled five times weekly through August 6, 1965 and after that samples were generally taken once weekly.

A continuous sampler was used to obtain composite samples of Velsicol's waste water discharge between April 8, 1966 and June 23, 1966.

Flow measurements at the sewer sampling stations were made in conjunction with water sampling using a current meter attached to a rigid metal rod. The meter was set

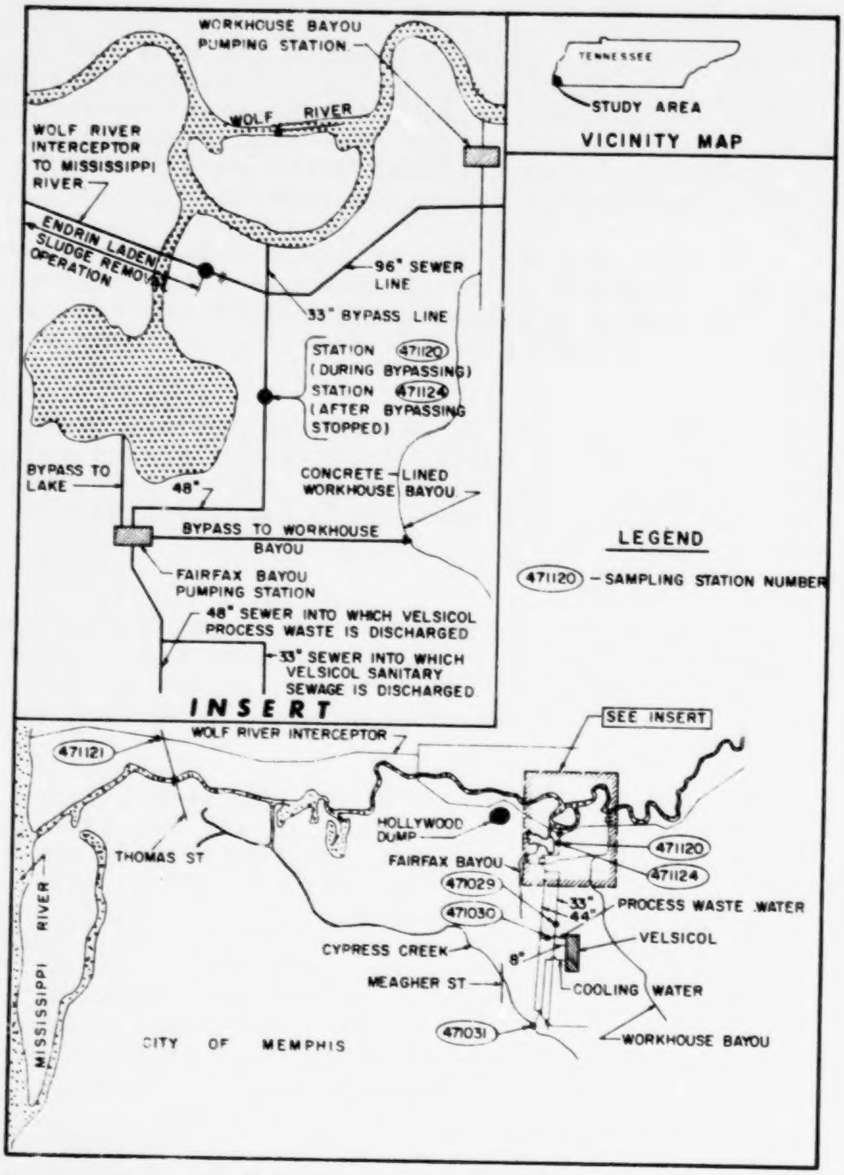

WORKHOUSE BAYOU PUMPING STATION
WOLF RIVER
WOLF RIVER INTERCEPTOR TO MISSISSIPPI RIVER
ENDRIN LADEN SLUDGE REMOVAL OPERATION
96" SEWER LINE
33" BYPASS LINE
STATION 471120 (DURING BYPASSING)
STATION 471124 (AFTER BYPASSING STOPPED)
BYPASS TO LAKE
48"
CONCRETE-LINED WORKHOUSE BAYOU
BYPASS TO WORKHOUSE BAYOU
FAIRFAX BAYOU PUMPING STATION
48" SEWER INTO WHICH VELSICOL PROCESS WASTE IS DISCHARGED
33" SEWER INTO WHICH VELSICOL SANITARY SEWAGE IS DISCHARGED
INSERT
TENNESSEE
STUDY AREA
VICINITY MAP
LEGEND
471120 – SAMPLING STATION NUMBER
SEE INSERT
WOLF RIVER INTERCEPTOR
471121
THOMAS ST
HOLLYWOOD DUMP
471120
471124
FAIRFAX BAYOU
471029
471030
33"
44"
PROCESS WASTE WATER
VELSICOL
CYPRESS CREEK
8"
MEAGHER ST
COOLING WATER
471031
WORKHOUSE BAYOU
MISSISSIPPI RIVER
CITY OF MEMPHIS

Figure 8 – Location of sampling stations on Memphis City sewer system. Sampling station number corresponds to those given in Table 3.

Table 3. Sampling stations, descriptions, and dates sampled on Memphis sewer system.

Station number*	Station name*	Location description	Sampling dates
471030	Velsicol-drop MH in railroad yard (Velsicol process waste discharge)	Manhole in 48-inch sanitary sewer	January 1965 through December 1968
471031	Velsicol cooling water discharge	Sewer discharge at Cypress Creek	January 1965 through October 1967
471029	Fairfax Bayou pumping station 33 below Velsicol	A manhole in the 33" sewer near Shainberg's	July 1965 through April 1966
471120	Wolf River interceptor bypass	First manhole on the 48" sewer above junction with the Wolf River interceptor	February 1965 through Dec. 1965 (bypassing period)
471024	Fairfax Bayou pump system discharge	First manhole on 48" sewer above junction with the Wolf River interceptor	December 1965 through April 1966 (bypass closed)
471121	Wolf River sewer at Thomas Street	Manhole in Wolf River interceptor at Thomas Street	January 1965 through April 1966 except for days when sewer surcharged

* Station numbers and names are those used by STORET, The Federal Water Pollution Control Administration's computer program used for storing and retrieving water quality data.

on the rod at 60 percent of the flow depth and lowered into the sewer. Velocities were then obtained from the meter rating curve.

Process Waste. Endrin concentrations as high as 4,600 ug/g were found in sludges or muds which had accumulated in the bottom of Cypress Creek into which Velsicol Chemical Corporation discharges. In late September and early October 1964, endrin concentrations as high as 20,040 ug/g were found in sludge accumulations in 3400 feet of the Wolf River interceptor sewer into which Velsicol discharges. A total of approximately 8,000 pounds of endrin was estimated to be present in the sewer. In the fall of 1965, Velsicol installed an incinerator and wastes formerly drummed and hauled to a dump were incinerated, as well as some waste solvents. An inplant survey during the period December 6-10, 1965, found an estimated 600 pounds per day of endrin in the incinerator feed which at one time could have been a potential source of endrin pollution to the Mississippi River.

The average endrin concentration of 686 grab samples of Velsicol process wastes (sampling station number 471030) collected between January 18, 1965 and September 30, 1967 was 146.99 ug/l with the values ranging from 0 to 12,113.04 ug/l. The average of 678 instantaneous discharge measurements taken at the time of sampling was 7.4 cu.ft./sec. with the values ranging from 23.2 cu.ft./sec. to 0.7 cu.ft./sec. Based on the daily grab samples, the average endrin load discharged to the Mississippi River was estimated to be 7.0 lbs/day.

Based upon results obtained during the first 31 weeks of sampling, it was determined that average weekly concentrations of endrin in the process waste water discharge seldom exceeded 168 ug/l (Table 4) and this was used as a control limit. When this limit is exceeded, the Executive Secretary of the Tennessee Stream Pollution Control Board is informed so that control action can be taken.

Before March 19, 1966 the average concentration was 116.43 ug/l; however, between March 19, 1966 and July 30, 1966, the average concentration rose to 549.64 ug/l. Table 11 shows the weekly averages. The upper control limit of 168 ug/l was exceeded 29 times between January 1965 and October 1966. The control was not exceeded from November

Table 4. Weekly mean concentrations of endrin in Velsicol process waste water, showing dates when control limit was exceeded.

Week Ending	Concentrations of endrin (µg/l)		Number of days sampled
	168	168*	
1-23-65	-	447.08	5
1-30	35.11	-	5
2-06	75.25	-	5
2-13	43.50	-	5
2-20	46.51	-	5
2-27	39.53	-	4
3-06	33.59	-	5
3-13	-	430.74	5
3-20	24.86	-	5
3-27	23.26	-	5
4-03	58.26	-	5
4-10	27.11	-	4
4-17	88.72	-	5
4-24	36.41	-	5
5-01	17.40	-	5
5-08	36.34	-	6
5-22	119.19	-	5
5-29	51.64	-	5
6-05	92.86	-	4
6-12	20.76	-	5
6-19	-	409.73	5
6-26	-	226.55	5
7-03	-	362.45	5
7-10	94.55	-	5
7-17	78.45	-	5
7-24	130.96	-	5
7-31	151.98	-	6
8-07	-	230.46	6
8-14	96.71	-	5
8-21	68.78	-	6
8-28	78.00	-	5
9-04	67.88	-	5
9-11	61.28	-	4
9-18	-	227.10	5
9-25	-	237.65	5
10-02	-	181.60	5
10-09	-	178.16	5
10-16	119.76	-	5
10-23	124.27	-	6
10-30	92.71	-	5
11-06	82.41	-	5

* When the control limit of 168 µg/l is exceeded, the Executive Secretary of the Tennessee Stream Pollution Control Board is informed.

Table 4. Weekly mean concentrations of endrin in Velsicol process waste water, showing dates when control limit was exceeded.

Week Ending	Concentrations of endrin (µg/l)		Number of days Sampled
	168	168*	
11-13	119.31	-	4
11-20	158.80	-	5
11-27	70.99	-	4
12-04	40.62	-	5
12-11	45.71	-	5
12-18	46.26	-	5
12-25	145.21	-	4
1-01-66	-	188.61	4
1-08	46.76	-	5
1-15	68.36	-	5
1-22	61.00	-	5
1-29	19.98	-	4
2-05	68.01	-	4
2-12	-	235.86	5
2-19	-	195.20	5
2-26	79.16	-	4
3-05	92.02	-	5
3-12	144.37	-	5
3-19	149.37	-	5
3-26	145.12	-	5
4-02	-	1808.24	5
4-09	-	524.94	5
4-16	-	418.57	6
4-23	164.66	-	7
4-30	-	350.41	7
5-07	-	337.28	7
5-14	-	2146.27	7
5-21	-	667.15	6
5-28	88.14	-	5
6-04	-	212.19	4
6-11	61.91	-	5
6-18	-	293.31	5
6-25	35.78	-	5
7-02	-	717.31	5
7-09	-	273.08	4
7-16	65.94	-	5
7-23	-	432.75	5
7-30	-	679.54	5
8-06	86.56	-	5
8-13	74.73	-	5
8-20	30.68	-	5
8-27	27.19	-	5
9-03	161.20	-	5
9-10	-	214.42	4

Table 4. Weekly mean concentrations of endrin in Velsicol process waste water, showing dates when control limit was exceeded.

Week Ending	Concentrations of endrin (µg/l)		Number of days Sampled
	168	168*	
9-17	32.18	-	5
9-24	8.21	-	5
10-01	-	291.89	5
10-08	57.96	-	5
10-15	62.77	-	5
10-22	-	363.28	5
10-29	76.75	-	5
11-05	36.29	-	5
11-12	67.10	-	4
11-19	42.14	-	5
11-26	80.80	-	4
12-03	63.52	-	5
12-10	42.35	-	5
12-17	27.61	-	5
12-24	18.24	-	5
12-31	50.26	-	4
1-07-67	12.09	-	4
1-14	.00	-	5
1-21	.00	-	5
1-28	22.46	-	5
2-04	27.59	-	5
2-11	6.06	-	5
2-18	9.28	-	5
2-25	7.34	-	4
3-4	33.76	-	5
3-11	17.56	-	5
3-18	16.36	-	4
3-25	10.62	-	3
4-1	35.32	-	5
4-8	21.78	-	4
4-15	29.79	-	5
4-22	10.83	-	4
4-29	24.40	-	5
5-6	20.08	-	6
5-13	2.39	-	3
5-20	16.90	-	4
5-27	7.49	-	5
6-3	6.51	-	3
6-10	10.11	-	5
6-17	6.91	-	4
6-24	34.81	-	4
6-31	12.25		5
7-8	10.44	-	3
7-15	22.26	-	4

Table 4. Weekly mean concentrations of endrin in Velsicol process waste water, showing dates when control limit was exceeded.

Week Ending	Concentrations of endrin (µg/1)		Number of days Sampled
	168	168*	
7-22	5.68	-	5
7-29	9.02	-	5
8-5	6.55	-	5
8-12	15.19	-	4
8-19	1.59	-	5
8-26	6.07	-	4
9-2	66.20	-	5
9-9	28.63	-	3
9-16	13.99	-	5
9-23	4.56	-	5
9-30	4.82	-	5
10-7	3.57	-	5
10-14	20.20	-	5
10-21	19.79	-	5
10-28	47.44	-	5
11-4	61.99	-	5
11-11	12.12	-	4
11-18	59.72	-	5
11-25	16.74	-	4
12-2	3.19	-	4
12-9	41.59	-	5
12-16	3.68	-	5
12-23	10.35	-	5
12-30	6.45	-	4
1-6-68	10.99	-	4
1-13	8.02	-	4
1-20	26.75	-	2
1-27	9.21	-	5
2-3	6.61	-	5
2-10	15.52	-	4
2-17	8.50	-	5
2-24	12.11	-	3
3-2	16.12	-	5
3-9	6.45	-	5
3-16	15.81	-	5
3-23	14.28	-	4
3-30	9.72	-	3
4-6	16.64	-	2
4-13	7.78	-	4
4-20	7.67	-	5
4-27	24.19	-	5
5-4	10.57	-	5
5-11	7.04	-	2

Sewer closed - No samples May 8 - June 17

Table 4. Weekly mean concentrations of endrin in Velsicol process waste water, showing dates when control limit was exceeded.

Week Ending	Concentrations of endrin (µg/l) 168	168*	Number of days Sampled
Samples from June 18 - October 10 collected at Station 471031			
6-22	39.10	-	4
6-29	12.97	-	5
7-6	8.46	-	4
7-13	9.17	-	5
7-20	2.77	-	5
7-27	29.28	-	5
8-3	4.49	-	5
8-10	45.33	-	5
8-17	30.85	-	5
8-24	13.78	-	5
8-31	18.95	-	5
9-7	12.65	-	4
9-14	5.36	-	5
9-21	13.93	-	5
9-28	1.54	-	5
10-5	0.75	-	5
10-12	4.64	-	5
Resumed sample collection at 471030			
10-19	5.83	-	5
10-26	8.44	-	5
11-2	3.79	-	5
11-9	2.21	-	5
11-16	5.24	-	4
11-23	9.15	-	5
11-30	6.19	-	4
12-7	1.52	-	4
12-14	7.27	-	5
12-21	12.25	-	5
12-28	2.72	-	4

1966 to December 31, 1968. It is concluded that discharges from the Velsicol Chemical Corporation in Memphis, Tennessee were a significant source of endrin pollution to the Mississippi River. Sampling of wastes from the Velsicol plant indicates no seasonal trend in the quantity of endrin being discharged.

Endrin in agricultural runoff was the other significant source of endrin pollution. Project studies in the Yazoo and Big Black River basins showed that endrin concentrations in these rivers tended to be higher during May, June, July, and August, coinciding with the time of endrin application to crops. Thus, endrin from agricultural sources should contribute more to the pollution load during the spring and summer months, when greater quantities of water are present in the Mississippi and Atchafalaya Rivers for dilution.

Table 5 shows the calculated endrin concentrations in the Mississippi River at Memphis, which would be produced by Velsicol process waste water discharges containing in excess of 500 µg/l of endrin. Computations were made assuming the endrin concentrations in the river were zero and complete lateral mixing had occurred. These data show that with the right combination of river flow and endrin concentration in the process waste water, the endrin concentrations in the river water approach levels reported to be toxic to fish. For example, on March 31, 1966 the concentration in the river was estimated to be 0.15 µg/l for the instant when Velsicol discharged wastes having an endrin concentration of 7895.83 µg/l; endrin concentrations toxic to some fish range from 0.10 to 0.20 µg/l. The highest endrin concentration in the Mississippi River estimated using the results of the process waste composite samples was 0.05 µg/l. Even though some of the instantaneous concentrations estimated in the river were above levels which are toxic to some fish, the concentrations evidently did not persist for sufficient time to cause a fish kill or were not high enough to be toxic to the fish present in the river.

The composite samples tended to have lower concentrations than the grab samples. The average endrin concentration of the 60 composite samples taken continuously between April 8, 1966 and June 23, 1966 was 384.06 µg/l; the average of 64 grab samples taken during the same period was 481.21.

It is concluded that the Velsicol process waste discharge was a more significant source of endrin pollution to the Mississippi River prior to November 1966 than thereafter.

Table 5. Calculated endrin concentrations in the Mississippi River at Memphis, Tennessee which would be produced by Velsicol process waste discharges exceeding 500 µg/l of endrin, January 18, 1965 through December 1968.

	Measured discharge		Endrin (µg/l) measured in Velsicol waste based on		Calculated µg/l of endrin in Miss R. at Memphis based on endrin in Velsicol process waste determined by	
Date	Velsicol proc. waste (cfs)	Miss. R. at Memphis (1000 cfs)	Grab samples	Composite samples	Grab samples	Composite samples
1-18-65	6.0	597	1,750.00	-	0.01	-
3-8	6.4	645	1,199.00	-	0.01	-
3-10	11.2	712	663.00	-	0.01	-
6-15	16.5	485	1,353.72	-	0.02	-
6-25	5.2	360	623.48	-	0.01	-
6-29	4.6	343	656.05	-	0.01	-
7-2	6.0	302	859.52	-	0.02	-
8-2	5.7	325	765.00	-	0.01	-
9-17	6.9	398	749.13	-	0.01	-
9-21	6.4	367	658.41	-	0.01	-
10-6	5.8	513	538.47	-	0.01	-
2-10-66	5.3	188	779.33	-	0.02	-
3-31	6.8	349	7,895.83	-	0.15	-
4-5	7.3	347	1,061.07	-	0.02	-
4-6	7.7	338	835.56	-	0.02	-
4-9	8.0	340	-	1,684.44	-	0.04
4-11	7.0	349	1,447.20	668.33	0.03	0.01
4-13	8.3	351	-	500.66	-	0.01
4-15	7.9	387	-	868.00	-	0.02
4-17	8.6	417	-	2,496.92	-	0.05
4-25	9.5	560	-	1,013.94	-	0.02
4-26	7.8	597	1,219.72	517.04	0.02	0.01
5-2	7.5	726	535.10	959.50	0.01	0.01
5-3	7.3	747	-	638.88	-	0.01
5-4	7.1	773	1,091.14	-	0.01	-
5-10	8.5	901	-	545.23	-	0.01
5-11	8.5	909	2,229.41	-	0.02	-
5-12	9.3	909	12,113.04	-	0.12	-
5-15	7.0	882	-	2,100.00	-	0.02
5-19	8.4	755	-	951.21	-	0.01
5-20	8.5	740	3,170.16	-	0.04	-
5-31	4.6	548	598.28	-	0.01	-
6-14	9.7	287	596.07	-	0.02	-
6-27	7.1	289	2,047.77	-	0.05	-
6-29	5.8	242	676.06	-	0.02	-
6-30	4.6	228	562.86	-	0.01	-
7-6	6.3	222	757.58	-	0.02	-
7-20	8.7	232	782.15	-	0.03	-
7-26	7.4	188	1,621.43	-	0.06	-
7-27	7.8	183	1,545.11	-	0.07	-
8-29	11.1	193	590.43	-	0.03	-
9-8	11.5	152	578.00	-	0.04	-
9-27	8.1	183	979.50	-	0.04	-
10-20	6.3	162	946.30	-	0.04	-
10-21	7.3	166	656.96	-	0.03	-

Note: All remaining samples after October 2, 1966 thru December 31, 1968 contained less than 500 µg/l.

Cooling Water. Velsicol cooling water discharges (sampling station number 471031) were normally sampled five times weekly during the period of January 18, 1965 through August 6, 1965 and endrin concentrations ranged from 0 to 154.00 µg/l with a mean of 12.47 for 143 grab samples. During the period of August 7, 1965 through September 1967, samples were normally taken once weekly and endrin concentrations ranged from 0 to 83.60 µg/l with a mean of 5.11 for 116 grab samples. The mean concentration for all 259 grab samples was 9.17 µg/l. Flows averaged less than one cubic foot per second during this period. Endrin loads ranged from 0 to 0.75 lbs/day with an average of 0.10 lbs/day for 229 samples collected when discharge measurements were made. The average endrin concentration for the process waste water was 16 times greater than that for the cooling water while the endrin load for the process waste water was 70 times greater than the average load in the cooling water. The cooling water is not a significant source of endrin pollution to the Mississippi River.

Sanitary Waste. At sampling station number 471029 on the 33-inch sewer into which Velsicol sanitary sewage is discharged, an average endrin concentration of 60.86 µg/l was found during the period July 13, 1965 through April 26, 1966 based on 192 grab samples. Only 30 flow measurements were made and the average endrin load was 1.20 lbs/day. The presence of endrin in this sewer could have been due to either of two factors or a combination of the two: (1) Endrin might have been present in sanitary sewage or (Grzenda (27) reported finding endrin concentrations in the 8-inch sewer ranging from 108.00 to 33.00 µg/l) or (2) endrin-contaminated sewage from the 48-inch line into which Velsicol process waste water was discharged was observed to be backed up into the sampling manhole on the 33-inch sewer. It did not appear that the sanitary sewage was a major source of endrin pollution to the Mississippi River.

City Sewers. During the removal of endrin-laden sludge from the Wolf River interceptor, the discharges from the Fairfax Bayou pumping station and the portion of the Wolf River interceptor above the pumping station discharge line were bypassed directly into Wolf River (Figure 8). Also, sewage was occasionally bypassed around the Fairfax Bayou pumping station into either a small lake near the pumping station or to Workhouse Bayou. The City of Memphis has now eliminated the bypassing of sewage into the lake and the bayou.

The bypass line was only a 33-inch sewer while the connecting sewers were 96 and 48 inches. This created the surcharging of the sewer system above the bypass. Because of this, the data collected from the manhole on the 48-inch line above the junction of the line with the Wolf River interceptor was grouped by two periods: 1. the period during bypassing, February 3, 1965 through December 22, 1965 (sampling station number 471120) and 2. the period after bypassing stopped, December 23, 1965 through April 26, 1965 (sampling station number 471024).

The results of the endrin analysis of samples collected under these two conditions were somewhat different. The mean load for the period of bypassing was 5.29 lbs/day based on 211 grab samples compared to 9.32 lbs/day based on 76 grab samples taken after bypassing stopped. The mean concentration based on 225 grab samples was 29.32 µg/l during bypassing while it was 47.56 µg/l after bypassing based on 83 grab samples.

To monitor the sludge cleaning operation, sampling was initiated at the Wolf River interceptor sewer at Thomas Street (sampling station number 471121). While the cleaning operation was in progress upstream no unusual discharges of endrin were noted. The mean concentration based on 133 grab samples was 9.11 µg/l while the load was 1.24 lbs/day based on 118 grab samples. However, for the first five days after the interceptor was reopened, December 23, 1965, extremely high endrin concentrations (mean of 180.72 µg/l) were detected with an average load of 51.33 lbs/day. These values were apparently the result of flushing solids from the cleaned portion of the interceptor, because the concentrations gradually became smaller as time progressed. After the sewer was flushed, during this initial five-day period, the mean concentration was 12.87 µg/l based on 31 grab samples while the average load was 3.86 lbs/day based on 29 grab samples up to February 15, 1966.

The flow in this section of the interceptor came from ground water infiltration during the time the sludge was being removed. Often the sewer was surcharged or flooded from backwater from the Mississippi River; from February 16, 1966 through March 25, 1966 the station was surcharged or flooded and no samples were taken. From March 26, 1966 through April 15, 1966 the mean load was 17.70 lbs/day based on 15 grab samples while the mean concentration was 42.28 µg/l based on 15 grab samples.

During the period of sampling it was concluded that endrin was being discharged through the Memphis City sewers to the Mississippi River.

Incinerator Feed. In the fall of 1965, the Velsicol Chemical Company installed an incinerator, and wastes, formerly drummed and hauled to a dump, were incinerated, together with some waste solvents. An in-plant grab sample survey during the period December 6-10, 1965, found the following endrin concentrations in the incinerator feed: December 6, 1965 - 1.558 x 10^8 µg/l; December 7, 1965 - 1.60 x 10^7 µg/l; December 8, 1965 - 5.1 x 10^6 µg/l; December 9, 1965 - 2.47 x 10^8 µg/l; and December 10, 1965 - 1.07 x 10^7 µg/l. On December 9 and 10, 1965, there were 1150 and 1015 gallons of incinerator feed, respectively. Based on these data, there were 2334 and 57.8 pounds of endrin in the incinerator feed, respectively. Flow data were not available for the other days; however, based on an average flow of 1083 gallons per day, there would be 1411.1, 144.9 and 46.2 pounds of endrin per day in the incinerator feed on December 6, 7, and 8, respectively. From these data it was estimated that there was a mean of 598.8 pounds per day of endrin in the incinerator feed during the five day period from December 6 through 10, 1965.

Formulators

Endrin Formulation. Endrin is normally formulated from the technical grade product into lower concentration liquids, dusts or granules. Endrin for use on cotton and certain other crops is formulated into a dust or a liquid concentrate and that for use on sugarcane into a granule. In the liquid formulation process, technical grade endrin (95 percent) crystals are dissolved in a suitable solvent such as xylene. An emulsifying agent is added to the endrin solution. Other insecticides such as methyl parathion are often combined with the endrin during the formulation. An emulsifiable liquid with a concentration of 1.5 to 1.6 pounds of endrin per gallon is the most widely produced product. Endrin dust is formulated by grinding technical grade endrin with a dry clay to produce a dust of 2 to 5 percent endrin content. Very little endrin dust is currently being formulated. Endrin granules are formulated by dissolving technical grade endrin in hot (110°F.) naptha. This solution is sprayed onto neutralized clay granules in a rotating drum to produce a final product of 2 percent endrin content.

None of these formulating processes produce any liquid waste per se, however, periodic washdowns of mixing tanks and formulating floor areas, accidental spills, etc., result in some endrin runoff to disposal pits. During periods of heavy rainfall, overflows from these waste disposal pits are potential sources of endrin.

Endrin in Formulating Plants Waste. Seven of 24 known plants formulating endrin with the Project study area were selected for investigation (Figure 9). The Swift & Company plant in Memphis, Tennessee; the Coahoma Chemical Company, Inc., in Clarksdale, Mississippi; the Riverside Chemical Company, Marks, Mississippi and the Louisiana Agricultural Supply Company in Baton Rouge, Louisiana were found to have relatively constant liquid discharges. These were monitored during June and July of 1966 for nine days each in the case of the first three plants and for 14 days at the latter plant. Samples were taken every two hours, four times a day, and composited daily in proportion to flow; flow measurements were made with a pygmy current meter. The Olin Mathison Chemical Company, Leland, Mississippi; the Valley Chemical Company, and Thompson Hayward Chemical Company produced only intermittent liquid wastes which could not be sampled continuously. At these plants grab samples of standing water in drainage ditches were taken as well as soil samples from incinerator pits and drainage ditches. Soil samples from incinerator pits were also taken at two other plants. Soil samples from the incinerator pits were taken at five locations and composited; the ditch samples were single grab samples.

A summary of the endrin concentrations and calculated endrin loads from the four plants with continuous discharges is given in Table 6. These results indicate that even during periods of endrin formulation only small quantities of endrin were contained in the liquid wastes leaving the plants. Table 7 shows that higher concentrations of endrin are contained in pit and ditch bottoms and in standing water on the plant grounds and these could be considered reservoirs of endrin. It is concluded that formulating plants are not a significant source of endrin pollution to the Mississippi River; however, they are a potential source of pollution to ground water and local lakes and streams.

To prevent pollution of ground water and streams in the vicinity of the formulating plants, it is recommended, based

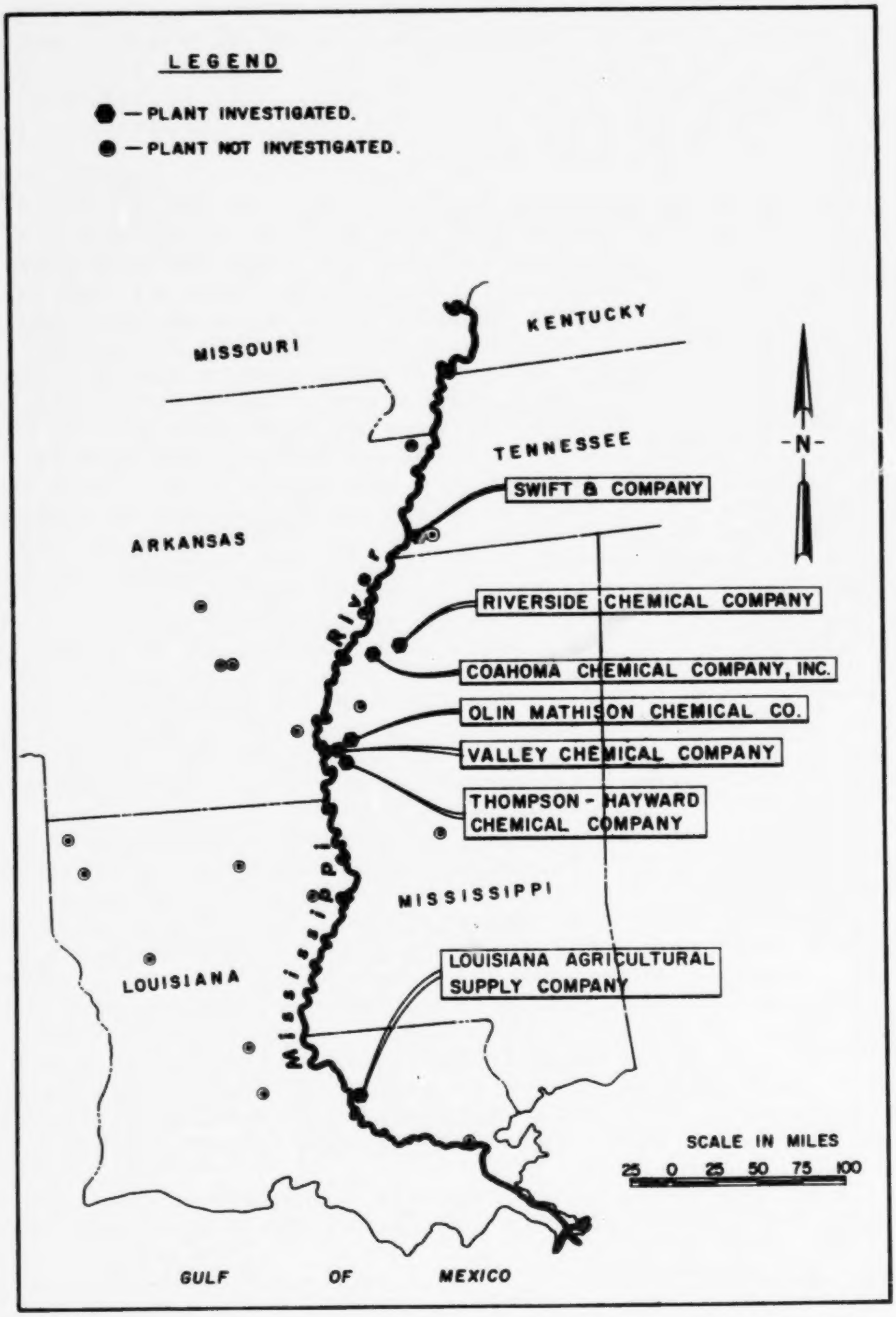

LEGEND
● — PLANT INVESTIGATED.
● — PLANT NOT INVESTIGATED.
MISSOURI
KENTUCKY
TENNESSEE
-N-
SWIFT & COMPANY
ARKANSAS
RIVERSIDE CHEMICAL COMPANY
COAHOMA CHEMICAL COMPANY, INC.
OLIN MATHISON CHEMICAL CO.
VALLEY CHEMICAL COMPANY
THOMPSON - HAYWARD CHEMICAL COMPANY
Mississippi River
MISSISSIPPI
LOUISIANA
LOUISIANA AGRICULTURAL SUPPLY COMPANY
SCALE IN MILES
25 0 25 50 75 100
GULF OF MEXICO

Figure 9 – Location of known plants formulating endrin in Lower Mississippi River Basin.

Table 6. Endrin concentrations and loads in process waste from formulating plants during 1966.

Formulating plant	Days Sampled	µg/l of endrin mean	range	lbs/day of endrin mean	range
Swift & Co.	9	7.32	25.74 - 0.00	.0001	0.0003- .0000
Coahoma Chem. Co.	9	0.23	1.18 - 0.01	.0001	0.0004- .0001
Riverside Chem. Co.	9	0.24	0.58 - 0.02	0.001	0.002- .001
La. Agric. Supply Co.	14	24.06	208.20 - 0.01	0.053	0.394- .001

Table 7. Endrin in standing water and soil from drainage ditches and incinerator pits at formulating plants during 1966.

Formulating plant and type of sample	Concentration of endrin in µg/l or ng/g
Thompson-Hayward	
Water from drainage ditch	0.90
Soil from drainage ditch	2246.60
Soil from incinerator pit	4437.70
Olin Mathieson	
Water from drainage ditch	0.60
Soil from drainage ditch	0.0
Soil from incinerator pit	14.01
Valley Chemical	
Water from drainage ditch	80.54
Soil from drainage ditch	0.0
Soil from incinerator pit	3456.00
Coahoma	
Soil from incinerator pit	741.20*
Riverside	
Soil from incinerator pit	0.16

* Average of 2 composite samples

on suggestions by the National Agricultural Chemical Association (28) that: 1. formulating tanks should be located in pits and surrounded by low retaining walls to contain spills and contaminated wash water, and floor drains and pumps should be provided to remove these liquid wastes; 2. all endrin contaminated liquid wastes should be detoxified by acid treatment and then drained and pumped to a tight-bottom evaporating pond or if combustible, burned in a specially designed organic liquid waste incinerator; 3. all combustible containers, such as bags and fiber drums, should be burned in an incinerator; and 4. all used metal drums which contained endrin should be sealed and stored in a fenced area prior to being shipped to a professional drum reclaiming firm.

Agriculture

Endrin Use in Mississippi River Basin. Endrin has been utilized as an insecticide in all of the major agricultural production areas of the United States. However, information obtained from Shell Chemical Company, one of the two manufacturers of endrin, indicates that endrin used on cotton accounted for over 50 percent of that Company's production from 1953 through 1964 (29).

In order to obtain a broad perspective of endrin use in areas drained by the Mississippi River and its tributaries, a general survey was made of agricultural use of endrin. This survey of endrin consisted of mailing a letter and a form to the State Extension Entomologists in 23 of the states (excluding Louisiana and Mississippi) in the Mississippi River Drainage Basin. Information pertinent to principal crop usage, years in use and peak years of use was requested. Of the 23 states contacted, only Kansas, Ohio, and West Virginia indicated no usage (Table 8). The other states indicated relatively minor use except the cotton-growing states of Alabama and Arkansas. Endrin has been used on approximately 14 different crops in the area. Mississippi and Louisiana were known large-scale users of endrin and other pesticides in their cotton growing regions. The use of endrin on sugarcane in Louisiana was widespread, but because of the levee systems, little of the drainage from the sugarcane fields reaches the Mississippi or Atchafalaya Rivers.

Endrin Use in Yazoo and Big Black River Basins. The Yazoo and Big Black River Basins (Figure 10), which have well-defined borders, are agriculturally oriented,

Table 8. Agricultural use of endrin in states partially or wholly within the Mississippi River Basin based on mail survey of State Extension Entomologists.

State	Crops on which used	Years in use	Peak use year(s)
Alabama	cotton	1955-1962	1959-1962
Arkansas	cotton	1955-1963	1957-1962
Colorado	wheat	1954-present	minor use
Georgia	tobacco & orchard mice control	1956-1960	minor use
Illinois	corn, cabbage & orchard mice control	1959-1965	1963-1964
Indiana	tobacco & orchard mice	-	minor use
Iowa	corn	1957-present	1957-1959
Kansas	---	-	-
Kentucky	tobacco	1955-1963	1958-1963
Louisiana*	cotton & sugarcane	1955-present	1959-1962
Minnesota	potatoes, sugar beets, cabbage & corn	1958-present	1959-1964
Mississippi*	cotton	1955-present	1959-1962
Missouri	corn, cotton, sorghum, tobacco	1961-1964	1963
Montana	wheat, barley	1954-present	minor use
Nebraska	corn	1954-1963	-
N. Carolina	tobacco & orchard mice	-	minor use
N. Dakota	potatoes & sugar beets	1959-1965	1961-1964
Ohio	---	-	-
Pennsylvania	---	-	minor use
S. Dakota	corn	-	minor use
Tennessee	cotton, tobacco, corn	1953-1963	1963
Virginia	orchard mice	1953-1961	minor use
W. Virginia	---	-	-
Wisconsin	---	-	minor use
Wyoming	wheat	1956	minor use

* Data on agricultural use of endrin in Louisiana and Mississippi was not obtained from mail survey, State Extension Entomologists; however, use in those States was well known to Project personnel from other sources.

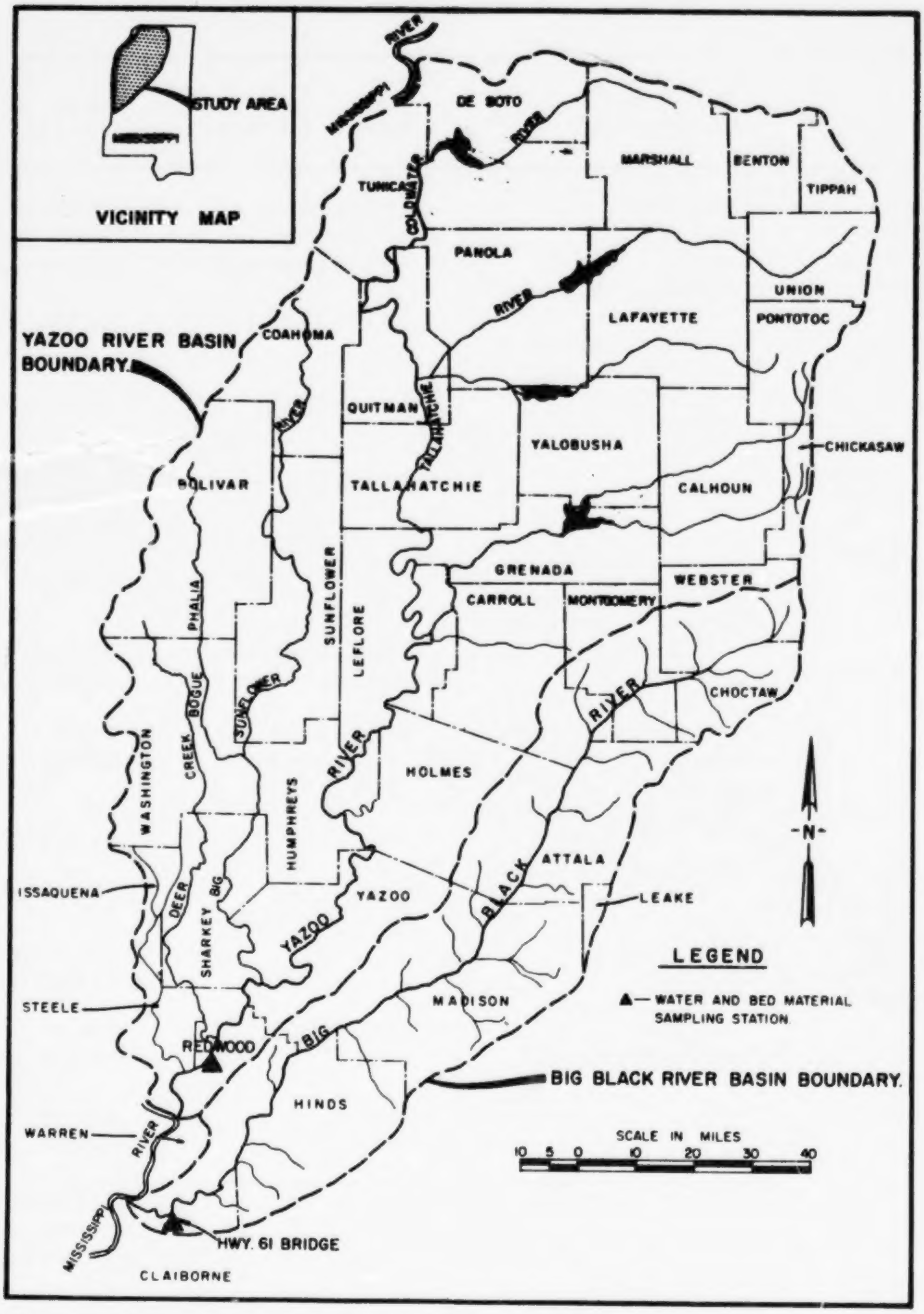

STUDY AREA
MISSISSIPPI
VICINITY MAP
YAZOO RIVER BASIN BOUNDARY
MISSISSIPPI RIVER
DE SOTO
COLDWATER RIVER
MARSHALL
BENTON
TIPPAH
TUNICA
PANOLA
UNION
PONTOTOC
LAFAYETTE
COAHOMA
QUITMAN
TALLAHATCHIE
YALOBUSHA
CHICKASAW
BOLIVAR
TALLAHATCHIE
CALHOUN
GRENADA
WEBSTER
CARROLL
MONTGOMERY
PHALIA
SUNFLOWER
LEFLORE
BOGUE
SUNFLOWER
CHOCTAW
WASHINGTON
CREEK
RIVER
YAZOO RIVER
HOLMES
HUMPHREYS
BLACK RIVER
ATTALA
-N-
ISSAQUENA
DEER
BIG
SHARKEY
YAZOO
LEAKE
LEGEND
▲— WATER AND BED MATERIAL SAMPLING STATION
STEELE
MADISON
REDWOOD
BIG
BIG BLACK RIVER BASIN BOUNDARY
HINDS
WARREN
RIVER
SCALE IN MILES
10 5 0 10 20 30 40
MISSISSIPPI
HWY. 61 BRIDGE
CLAIBORNE

Figure 10 — Yazoo and Big Black River Basins.

and contain one of the largest areas of cotton cultivation in the project area, were chosen for an intensive survey of the agricultural use of endrin. The lower Yazoo River Basin consists of an alluvial plain bounded by the Yazoo and Mississippi Rivers and characterized by a plantation system of farming, while the upper Yazoo River Basin consists of a rolling hilly terrain dominated by small-scale farming operations. Total area of this Basin is approximately 11,400 square miles and contains all or parts of thirty counties. The Big Black River Basin has a total area of approximately 3,400 square miles and contains all or parts of twelve counties. Its economy is dominated by small-scale farming operations.

Both Basins had a total of 1,197,000 acres planted to cotton in 1965 (30), which represents 81 percent of the State of Mississippi's total cotton acreage. Also, both Basins had a total of 1,344,000 acres planted to soybeans in 1965 (30), which represents 92 percent of Mississippi's total soybean acreage. Rice, corn, wheat and oats are also grown in the two-basin area. However, from an insecticide usage standpoint, cotton is of primary importance. An extensive survey of endrin use was made in the basins. Letters and a form were mailed to 36 county agents in the basins, and replies were received from 33.

The pesticide use data supplied on the Yazoo and Big Black River Basins was of sufficient detail to allow approximate estimations of endrin and other pesticides on a county basis. These data calculated for 1965 are shown summarized in Table 9. It was estimated that 9,490,800 pounds of technical grade endrin, toxaphene, DDT, sevin, and methyl parathion were applied to the crops in the two-basin area in 1965. Endrin represented about 5.5 percent of the total insecticides used, or 529,900 pounds.

Endrin in Yazoo and Big Black Rivers. Because of the relatively heavy use of endrin on the cotton in the Big Black and Yazoo River Basins, a study of the endrin concentrations in the water and bed materials of the two rivers was made.

Water and bed material samples were taken approximately bi-weekly for a total of 26 times during the period from April 1965 through March 1966 at Redwood, Mississippi, which is near the Yazoo's confluence with the Mississippi River, while samples were taken approximately bi-weekly for a total of 22 times during the period May 1965 through April 1966 on the

Table 9. Agricultural use of endrin and other insecticides during 1965 in the Yazoo-Big Black River Basins based on mail survey of county agents.

	Pounds of technical material		
County	Endrin	Other insecticides	Total
Attala	12,000	66,000	78,000
Benton	7,600	12,400	20,000
Bolivar	50,000	390,500	440,500
Calhoun	-	246,000	246,000
Carroll	4,200	107,500	111,700
Chickasaw	1,000	24 700	25,700
Choctaw	*	*	*
Claiborne	-	(cotton acreage small)	-
Coahoma	28,000	1,030,000	1,058,000
DeSoto	2,600	382,500	385,100
Grenada	-	75,000	75,000
Hinds	-	62,000	62,000
Holmes	30,000	690,000	720,000
Humpreys	*	*	*
Issaquena	10,000	77,000	87,000
Lafayette	-	102,800	102,800
Leake	-	(cotton acreage small)	-
Leflore	29,000	615,000	644,000
Madison	10,000	132,000	142,000
Marshall	2,800	53,500	56,300
Montgomery	-	64,800	64,800
Panola	39,000	497,000	536,000
Pontotoc	-	106,500	106,500
Quitman	34,000	238,000	272,000
Sharkey	39,000	95,500	134,500
Sunflower	36,000	880,000	916,000
Tallahatchie	54,000	1,245,000	1,299,000
Tate	1,000	24,600	25,600
Tippah	5,000	48,000	53,000
Tunica	22,500	296,000	318,500
Union	*	*	*
Warren	9,000	58,000	67,000
Washington	96,000	640,000	736,000
Webster	-	18,800	18,800
Yalobusha	7,200	210,000	217,200
Yazoo	-	471,800	471,800
Total	529,900	8,960,900	9,490,800

---

* No response received from county agent.

** Toxaphene, sevin, DDT and methyl parathion.

Big Black River at a point approximately 13 miles upstream from its confluence with the Mississippi River (Figure 10). Flow measurements were made on the same days water and river bed samples were obtained by the U. S. Geological Survey. The sampling design used during April and May of 1965 resulted in the collection of samples from five verticals located at the centroids of equal segments of discharge in the cross-section of the rivers. Individual samples were collected at 90, 70, 50, 30 and 10 percent of the total depth. Samples after May 1965 on the Big Black were a composite of five depth integrated samples. Samples taken on the Yazoo after May 1965 were either point or depth integrated samples depending on the river stage. A bed sample was taken at each of the five verticals. See Chapter 5, Pattern of Endrin Pollution, for details relative to sampling equipment and design.

Rainfall data were obtained from records published by the U. S. Weather Bureau. Thirty rainfall stations in the Yazoo Basin and 13 in the Big Black Basin were selected uniformly throughout the area. Monthly unweighted arithmetic averages of rainfall were calculated and used as an index to rainfall for each basin.

Endrin concentration in the Yazoo and Big Black tended to be highest during June, July and August (Figures 11 and 12) which coincides with the time of endrin application, which for 1965 began in late June and continued through August (31). Increases in endrin concentrations were also noted in January in the Big Black and in January and February in the Yazoo. These increases apparently resulted from quick runoff caused by the abnormally high rainfall during this period.

Examination of the data showed that endrin concentrations in the waters of the Yazoo exceeded a concentration of 0.10 µg/l on three sampling days and on five sampling days in the Big Black (Tables 10 and 11). This concentration of 0.10 µg/l, if maintained, is within the toxic range for some fish.

An unquantitated source of endrin from these rivers is that portion contained in the bed material. The mean endrin value of the five bed material samples taken on each sampling date are listed in Tables 10 and 11. Many of these mean values indicate significant concentrations of endrin but little is known about the amount or movement of these bed materials. It seems reasonable to conclude, however, that much of this material does reach the Mississippi River, especially during periods of high flow.

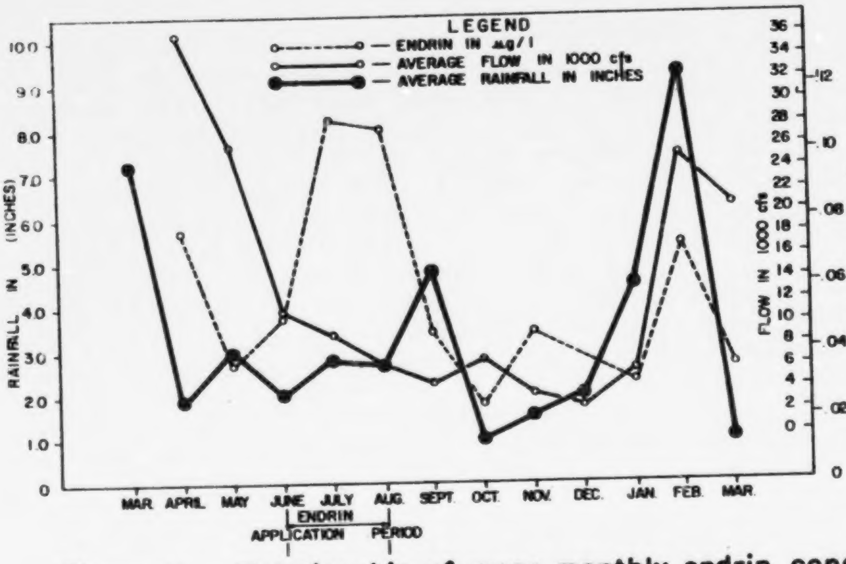


Figure 11 — Relationship of mean monthly endrin concentrations in the Yazoo River to river flow and rainfall, March 1965 through March 1966.

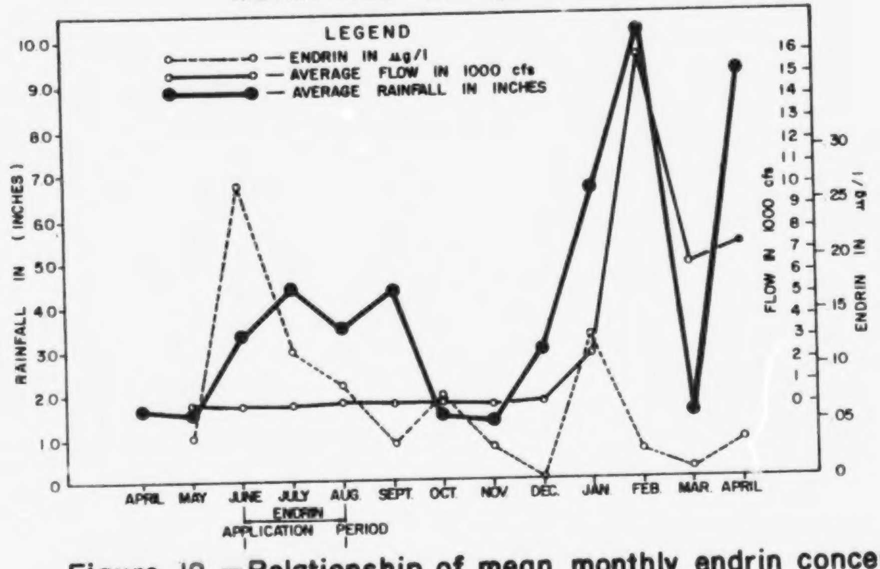


Figure 12 — Relationship of mean monthly endrin concentrations in the Big Black River to river flow and rainfall, May 1965 through April 1966.

Trends In The Production And Use of Endrin. Information received from the general survey of agricultural use of endrin, the survey of county agents in the Yazoo-Big Black River Basins, limited sales data of formulating companies, and information from Shell Chemical Company (29) indicated that endrin reached its peak production and use during the years 1960, 1961 and 1962, with 1960 as the apparent top year of production. Its use since 1963 has dropped considerably, with Shell Chemical Company (29) reporting a 1965 production of only 25 percent of their 1960 figure (Figure 13). Comparable production data from the Velsicol company was not available.

Table 10. Data on river flows, endrin concentrations in water and bed material for the Yazoo River.

Date	River Flow (1000 cfs)	Endrin in water (µg/1)	Endrin in bed material (ng/g)**
Apr. 5. 1965	33.0	0.27	0.00
Apr. 6	34.0	0.06	1.00
Apr. 7	35.0	0.07	0.00
Apr. 8	36.0	0.03	*
Apr. 9	37.0	0.00	*
Apr. 10	37.0	0.00	*
May 8	36.0	0.03	3.17
May 27	15.0	0.04	41.52
June 29	11.0	0.05	0.00
July 14	8.9	0.11	33.40
Aug. 12	7.0	0.16	0.00
Aug. 26	5.2	0.05	0.00
Sept. 23	4.5	0.04	0.00
Oct. 5	5.7	0.00	1.71
Oct. 19	7.4	0.03	0.00
Nov. 1	5.7	0.06	0.44
Nov. 16	2.4	0.04	0.00
Nov. 30	2.9	0.03	0.00
Dec. 15	2.3	0.00	0.00
Jan. 5, 1966	5.9	0.00	0.34
Jan. 18	5.4	0.04	0.45
Feb. 1	5.2	0.03	0.00
Feb. 16	45.0	0.11	0.00
Mar. 1	35.9	0.07	2.20
Mar. 15	16.3	0.02	0.00
Mar. 29	9.8	0.00	2.37

* No bed material samples taken.
** Nanograms per gram

Table 11. Data on river flows, endrin concentrations in water and bed material for the Big Black River.

Date	River Flow (cfs)	Endrin in water (µg/l)	Endrin in bed material (ng/g)
May 7, 1965	508	0.07	0.71
May 28	277	0.00	9.57
June 30	336	0.27	0.00
July 16	253	0.12	32.20
Aug. 12	443	0.12	0.43
Aug. 27	336	0.05	0.52
Sept. 22	287	0.03	0.00
Oct. 5	150	0.05	0.97
Oct. 19	241	0.08	0.00
Nov. 2	139	0.03	0.81
Nov. 16	159	0.04	0.46
Nov. 30	212	0.00	0.00
Dec. 15	309	0.00	0.73
Jan. 5, 1966	2300	0.18	0.00
Jan. 18	2480	0.11	0.21
Feb. 1	4610	0.02	0.25
Feb. 15	27200	0.02	*
Mar. 3	16100	0.00	0.00
Mar. 15	2190	0.00	0.00
Mar. 29	1020	0.00	0.00
Apr. 12	1720	0.03	0.00
Apr. 26	13000	0.03	0.40

* No bed material sample taken.

Seventeen pesticide formulating companies were asked to supply data relative to endrin sales in the Yazoo-Big Black Basins. Nine replies were received with four providing useful sales data indicative of trends in endrin usage over a three-year period. The sales figures for the years 1963, 1964, and 1965 from the four companies supplying endrin to the Yazoo and Big Black Basins substantiate that there has been a downward trend in endrin use in cotton growing areas (Figure 14). The amount of technical endrin sold in 1965 in the Yazoo and Big Black Basin area was only 59 percent of that sold

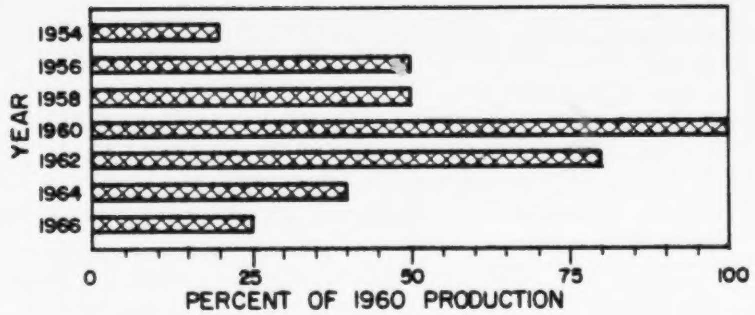


Figure 13 — Relative amounts of endrin produced during various years by Shell Chemical Company, using 1960 as a base.

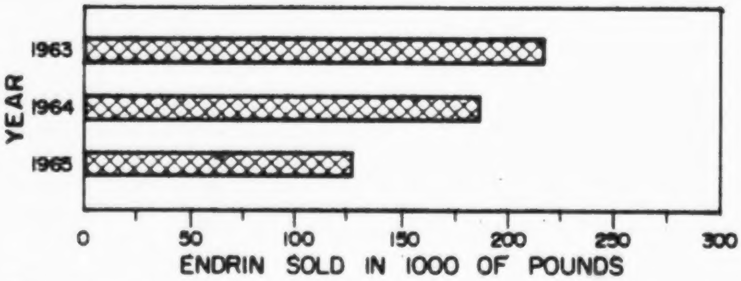


Figure 14 — Amount of technical endrin sold in the Yazoo and Big Black River Basins by four endrin formulating companies.

in 1963. One of the major uses of endrin was in the sugarcane growing areas of Louisiana; however, as endrin was withdrawn from the Louisiana State Experiment Station recommendations for use on sugarcane prior to the 1967 crop season, it is expected that the use of endrin in Louisiana will decline rapidly in the future and its significance as a source of pollution to the Louisiana coastal drainage basins will decrease.

It was concluded that agricultural use of endrin in the Yazoo-Big Black River Basins and other tributaries to the Mississippi River which drain agricultural areas were a significant source of endrin pollution to the Mississippi River. It is expected that the concentrations of endrin, from reduced agricultural usage and residual amounts from soils and river beds, in the Mississippi River will continue to decline.

Raw Sugar Factories

Sugarcane Production. Sugarcane is a perennial crop that contributes significantly to the economy of Louisiana, the only state in the Mississippi River Basin in which it is grown commercially. One-third to one-half of the crop is replanted each year. Planting involves preparation of the seedbed row, followed by the transplanting of portions of mature cane stalks containing two or more buds. The planted buds sprout in early spring and grow very rapidly during the hot, rainy summer and attain maturity in six to seven months. Harvest of the sugarcane usually begins in the middle of October.

During its growing cycle, the young sugarcane may be attacked by many insect pests, the most devastating of which is the sugarcane borer (*Diatraea saccharalis*). To control this pest, the pesticide endrin has been used almost exclusively since 1959. It is applied at a rate of 0.33 pounds of actual endrin per acre in the form of granules using either airplane or ground machine (32). Applications are made four to eight times a season at 14-day intervals beginning with the formation of the first joints or nodes. U. S. Department of Agrculture regulations prohibit the application of endrin during the last 45 days before harvest (32). According to Hensley et al., (33) the sugarcane borer has developed resistance to endrin, and other insecticides will be recommended for its control in the future.

Modern mechanical harvesting operations result in soil and other extraneous materials being picked up with the sugarcane, especially during periods of wet weather. This necessitates that the sugarcane be washed to remove these foreign materials prior to milling. In general, this is accomplished by spraying the cane with large volumes of water as it moves on conveyor belts into the mill. The spent wash water flows through ditches into a collection pond from where it is disposed of into waterways, including the Mississippi River for some raw sugar factories. The flow in the Mississippi River through this area usually averages about 240,000 cfs during the sugarcane processing season (October through December).

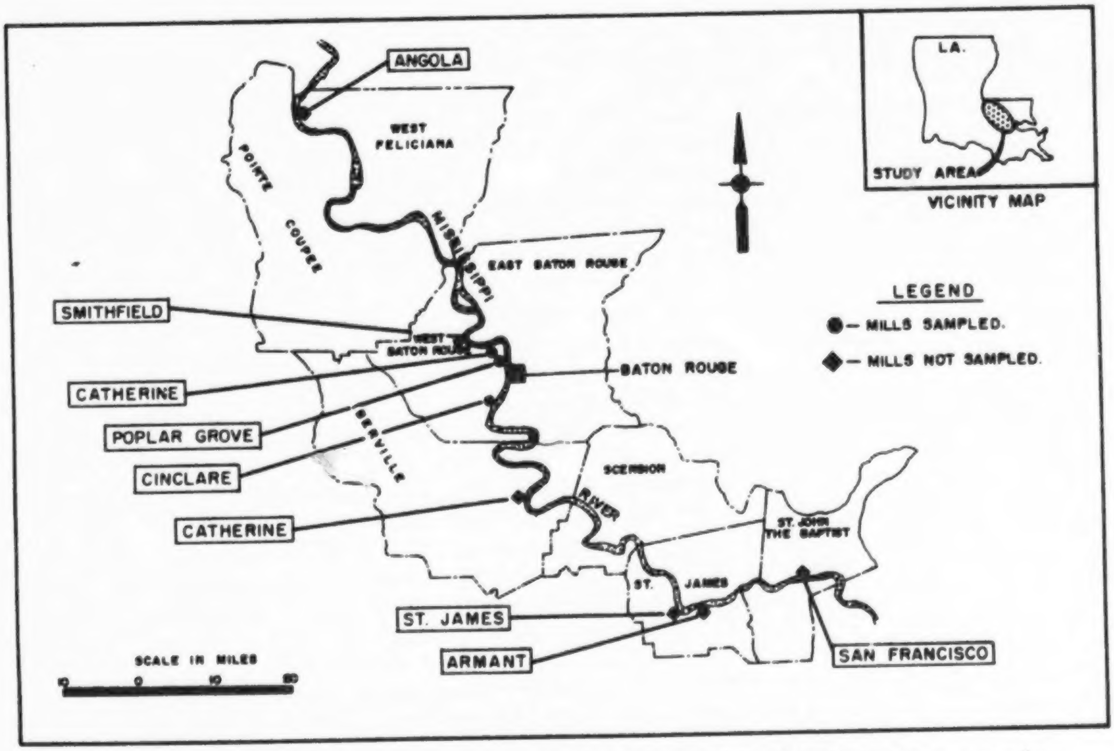
Endrin In Raw Sugar Factories Waste. Nine raw sugar factories in the study area discharge wastes into the Mississippi River (Figure 15). The factories are all located outside the levees along the Mississippi River in Louisiana. The wash waters are pumped over the levees into the river without treatment except for some crude settling which naturally occurs in the effluent ditches. These factories have a combined installed grinding capacity of 22,300 tons of sugarcane a day (34).

During the 60 to 90 day fall grinding season, the factories use large quantities of water in washing and processing the sugarcane. Four raw sugar factories, Cinclare, Catherine, Smithfield, and Poplar Grove, (Figure 15) were selected for sampling. They were chosen because they represent the range of sizes of all the factories, and comprise 53 percent of the total grinding capacity. General information on these factories is given in Table 12.

In 1964 and 1965 hurricanes damaged the sugarcane crops which resulted in relatively poor harvests. However, since this study was concerned primarily with the sugarcane washing operations at the grinding mills, and total endrin contributions were calculated on the rated capacities of the mills and not on the actual amount of cane ground, the results obtained are considered adequate for estimating the endrin contributions in the wash waters. Daily grab samples of wash waters, (excluding Saturdays and Sundays) were collected from the 1964 season beginning on November 5, 1964 and ending on January 4, 1965; bi-weekly grab samples were collected for the 1965 season beginning on October 22, 1965 and ending on December 22, 1966. Bed material samples were collected at the same locations that wash water samples were taken. Water samples were collected directly in glass

Table 12. Raw sugar factories sampled which discharge waste into the Mississippi River.

	Capacity in tons cane per day	lbs. sugar per ton of cane	Owner and Address
Catherine	1,000	165	Harry L. Laws Co. Brusly, Louisiana P. O. Box 104 Port Allen, La.
Cinclare	4,200	153	Harry L. Laws Co. Brusly, Louisiana
Poplar Grove	2,200	150	Mr. Charwin Wilkinson Port Allen, La. Rt. 2, Port Allen, La.
Smithfield	2,000	160	Milliken-Farnell & Co. 1002 Whitney Bldg. New Orleans, La. Rt. 1, Box 157 Port Allen, La.


ANGOLA
WEST FELICIANA
POINTE COUPEE
MISSISSIPPI
EAST BATON ROUGE
SMITHFIELD
WEST BATON ROUGE
BATON ROUGE
CATHERINE
POPLAR GROVE
IBERVILLE
CINCLARE
CATHERINE
ASCENSION
RIVER
ST. JOHN THE BAPTIST
ST. JAMES
ST. JAMES
ARMANT
SAN FRANCISCO
SCALE IN MILES
10
0
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20
LA.
STUDY AREA
VICINITY MAP
LEGEND
● — MILLS SAMPLED.
◆ — MILLS NOT SAMPLED.

Figure 15 — Location of raw sugar factories discharging waste into the Mississippi River.

quart bottles and sealed with teflon lined lids. Bottom sediments were scooped directly into quart bottles or obtained with a shovel and placed in bottles. Table 13 summarizes the data for samples collected at the mill sites during the 1964 grinding season. The flow values given in the table were estimated from the rated capacities of the pumps discharging the wash water over the levees.

Table 13. Endrin in wash water and bed material collected at raw sugar factories during 1964.

Factory	Number of Samples	Flow (cfs)	Wash Water Concentration (μg/1) Mean	Wash Water Concentration (μg/1) Range	Load (lbs/day) mean	Load (lbs/day) range
Catherine	12	2.2	0.06	0-0.13	.0007	0-.0015
Cinclare	16	4.5	0.05	0-0.44	.0012	0-.0106
Poplar Grove	18	2.8	0.04	0-1.00	.0006	0-.0151
Smithfield	14	1.7	6.89	.47-80.00	.0632	.0043-.7344

Factory	Number of Samples	Bed Material Concentration (ng/g) Mean	Bed Material Concentration (ng/g) Range
Catherine	9	17.48	1.39-36.24
Cinclare	13	7.90	0-26.26
Poplar Grove	16	5.23	0-46.92
Smithfield	7	88.29	27.29-180.00

The weighted average load of the four stations is 0.0153 pounds per day. Dividing this by 9,400 tons, the total daily capacity of the four mills gives an average endrin discharge of 1.63 (10^{-6}) pounds per day per ton of sugarcane processed. Assuming this figure is representative of the nine mills, a total endrin load of approximately 0.036 pounds per day, based on rated mill capacity, would be discharged to the Mississippi River during the fall grinding season. During the fall the Mississippi River flow is generally in the range of 240,000 cu.ft./sec. Discharging 0.036 pounds of endrin into a flow 240.000 cu.ft./sec. gives a concentration of 2.78×10^{-5} µg/l, a value approximately 10,000 times lower than concentrations known to be lethal to some fish. Also, this concentration is approximately 3,000 times less than a yearly average concentration the Project found in the Mississippi River upstream from raw sugar factories.

During 1965, wash water sampling of the factories was done primarily to verify the results found in 1964. The Catherine factory did not operate. Five samples were collected at Poplar Grove, two from Cinclare, and one from Smithfield. The results of these samples ranged from 0.02 µg/l to 1.00 µg/l which is essentially the same as observed in 1965.

In addition to sampling at the factory site in 1965 at the Cinclare factory, four samples were collected at the wash water discharge point at the Mississippi River. The results ranged from non-detectable to 0.08 µg/l with an average of 0.04 µg/l. This indicates that the endrin content of the wash water entering the river is essentially of the same magnitude as that coming directly from the plant although endrin concentration appears to have been accumulating in the beds of the outfall ditch (Table 12.)

During 1966 when there was no hurricane in Louisiana, eighteen wash water samples were collected from Cinclare and eighteen from Smithfield. The average endrin concentration in the samples from Cinclare was 0.12 µg/l, and from Smithfield 0.11 µg/l. These concentrations were in the same range as the samples collected during 1964 and 1965, indicating that the hurricanes of 1964 and 1965 did not significantly affect the endrin concentrations in the cane wash water waste.

Three process water samples were collected at both the Cinclare and Poplar Grove factories during 1965. The endrin concentrations for the six samples combined ranged from non-detectable to 0.71 µg/l with the average being 0.17 µg/l. During 1966, eighteen process water samples were collected at Cinclare. The endrin concentrations ranged from non-detectable to 0.29 µg/l, with the average being 0.10 µg/l. These concentrations are comparable to those found in the wash water. The process flows at both factories are estimated to be equal to the wash water flows; consequently, the process waters of the factories probably contribute an endrin load to the Mississippi River of the same magnitude as the wash waters.

Sugarcane wash and process water from the raw sugar factories investigated did not significantly contribute to the endrin load of the Mississippi River and it is concluded that raw sugar factories are not a significant source of endrin pollution to the Mississippi River.

CHAPTER 5

PATTERN OF ENDRIN POLLUTION

Historical Occurrence of Endrin

Pollution surveillance of many of the nation's waterways has been an activity of the Federal Water Pollution Control Administration (previously the Division of Water Supply and Pollution Control, U. S. Public Health Service). Since 1950 this agency has operated over 100 sampling stations on the major rivers of the United States, including the surface waters of the Mississippi River Basin. The carbon adsorption method was used for collection of samples and this method and analytical procedures are described by Breidenbach et al. (35). It is recognized that quantitative adsorption on, and desorption from activated carbon of all organic substances does not always occur. Thus, values for endrin measured in CAM samples are only minimum values.

Results of the analysis of selected CAM samples for endrin for the water years 1958-1964 (Oct. 1 through Sept. 30) by the pollution surveillance system are presented by Breidenbach et al. (35) and Gunnerson (36). These data for the Mississippi River Basin are presented in Figure 16. Results of the analysis of samples for endrin in the Mississippi River Basin were reported by Breidenbach et al. (35) and Green et al. (37) for the years 1964 through 1965. These data are given in Figure 17.

Because of the recurrent fish kills on the lower Mississippi River which took place during the fall and winter months, and the identification of endrin as the cause of the 1963-64 kill, a large number of CAM samples collected since 1958 were analyzed for endrin. The location of stations from which these samples were collected is shown in Figure 18. Results of these analyses are shown in Figure 19.

It was concluded from the data presented in Figure 19, that "concentrations of endrin have shown a general decrease since about the Spring of 1964, although a single sample from West Memphis during the 1965 synoptic survey approached earlier maxima." It was further concluded that the results

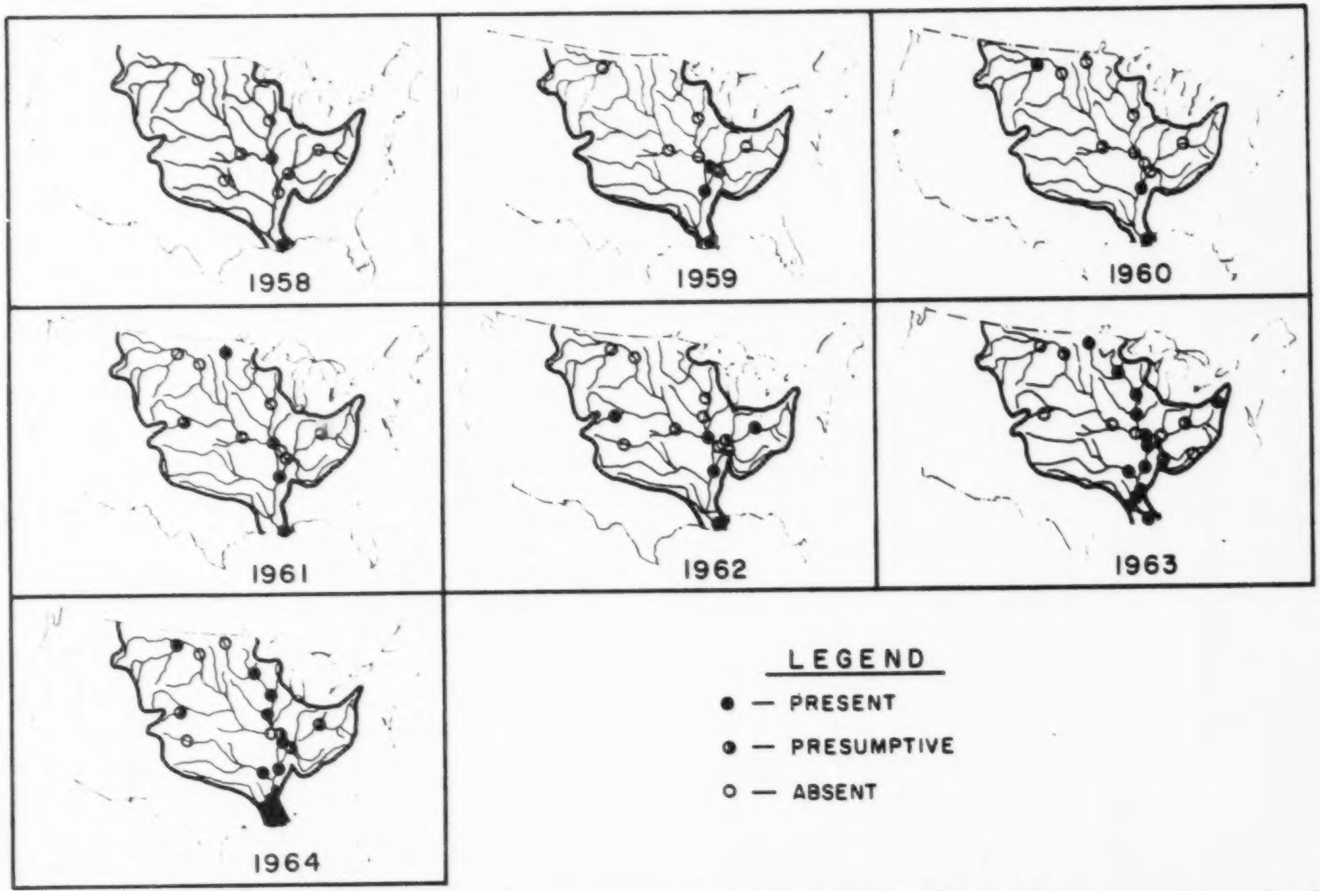
1958
1959
1960
1961
1962
1963
1964
LEGEND
● — PRESENT
◐ — PRESUMPTIVE
○ — ABSENT

Figure 16 — Historical occurrence of endrin in Mississippi River Basin as determined by selected pollution surveillance system CAM samples for water years 1958-64, from Breidenbach et al. (35) and Gunnerson (36).

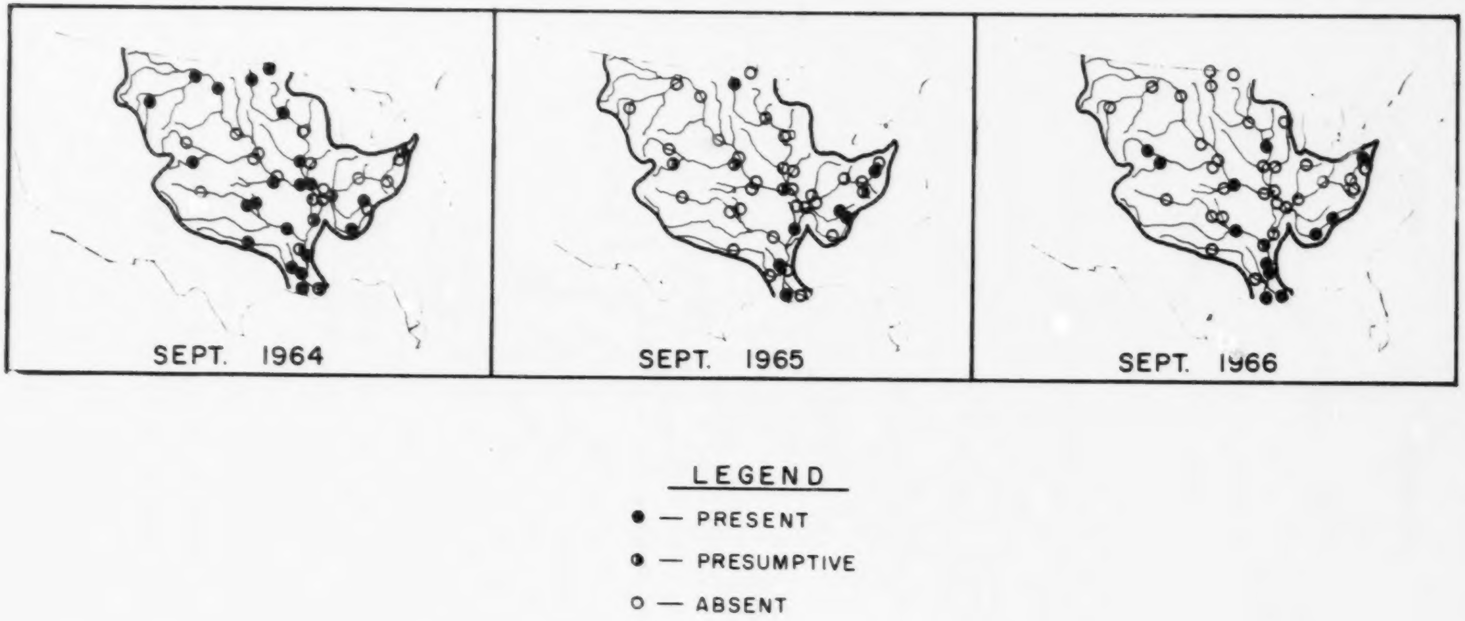
SEPT. 1964
SEPT. 1965
SEPT. 1966
LEGEND
● — PRESENT
◐ — PRESUMPTIVE
○ — ABSENT

Figure 17 — Occurrence of endrin in Mississippi River Basin as determined by pollution surveillance system from annual synoptic survey for 1964-65, from Breidenbach et al. (35) and Green et al. (37).

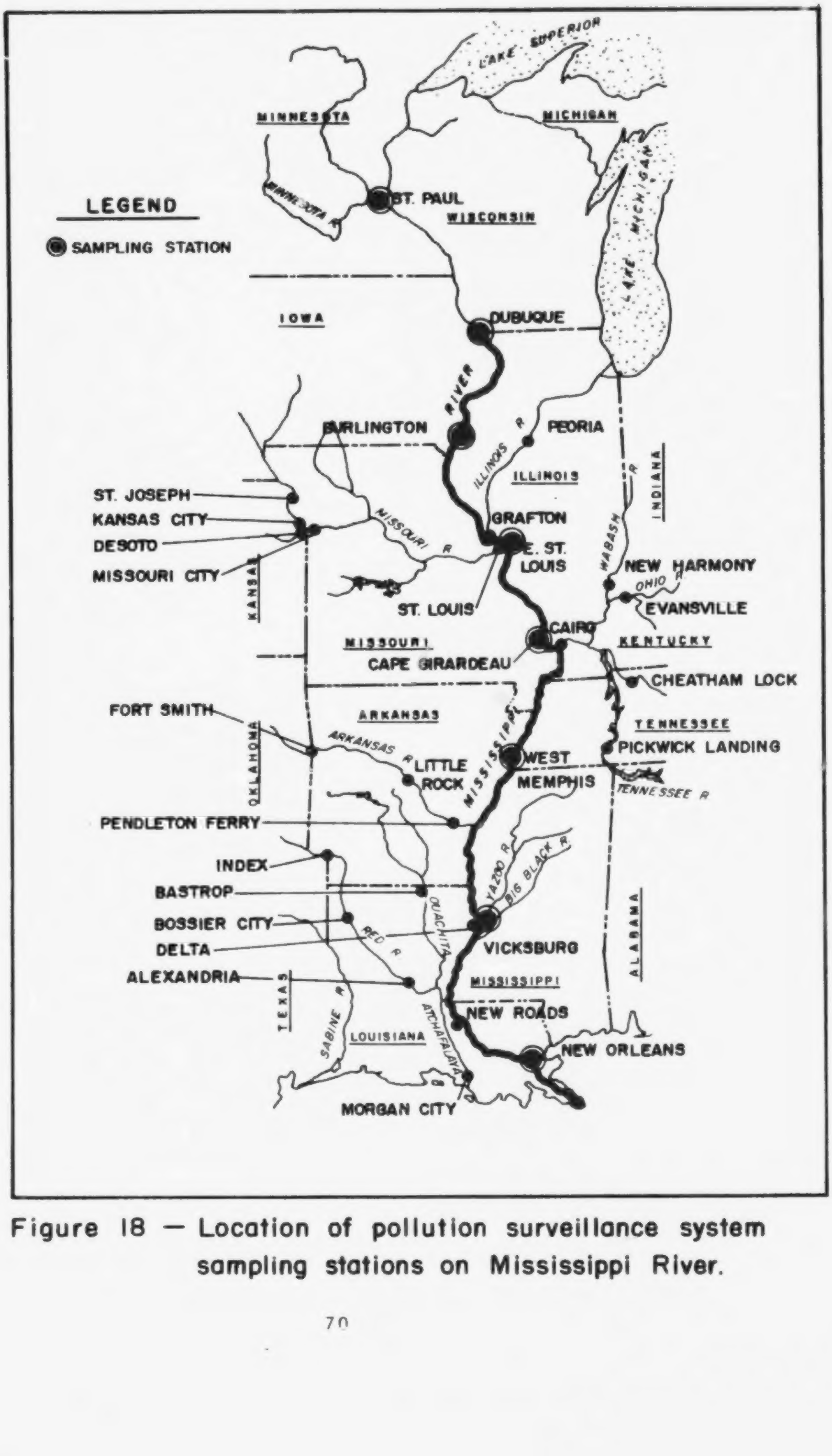
LAKE SUPERIOR
MINNESOTA
MICHIGAN
MINNESOTA R
ST. PAUL
WISCONSIN
LEGEND
SAMPLING STATION
LAKE MICHIGAN
IOWA
DUBUQUE
RIVER
BURLINGTON
PEORIA
ILLINOIS R
ILLINOIS
INDIANA
ST. JOSEPH
KANSAS CITY
DESOTO
MISSOURI CITY
MISSOURI R
GRAFTON
E. ST. LOUIS
WABASH R
NEW HARMONY
OHIO R
EVANSVILLE
KANSAS
ST. LOUIS
CAIRO
MISSOURI
CAPE GIRARDEAU
KENTUCKY
CHEATHAM LOCK
FORT SMITH
ARKANSAS
TENNESSEE
ARKANSAS R
MISSISSIPPI
WEST MEMPHIS
PICKWICK LANDING
LITTLE ROCK
OKLAHOMA
TENNESSEE R
PENDLETON FERRY
INDEX
YAZOO R
BIG BLACK R
BASTROP
BOSSIER CITY
OUACHITA
DELTA
VICKSBURG
RED R
ALABAMA
ALEXANDRIA
MISSISSIPPI
TEXAS
SABINE R
ATCHAFALAYA
NEW ROADS
LOUISIANA
NEW ORLEANS
MORGAN CITY

Figure 18 — Location of pollution surveillance system sampling stations on Mississippi River.

of the synoptic pesticides surveys of 1964 and 1965 (Figure 17) and the examination of stored carbon adsorption extracts for water year 1958 through 1965 (Figure 16) revealed: "Endrin occurrence reached a maximum, particularly in the lower Mississippi River in the Fall of 1963 (the first quarter of water year 1964). Since then, endrin levels have decreased." It was concluded from the synoptic surveys in 1964, 1965, and 1966 and stored carbon adsorption extracts for water years 1958 through 1964 that "Endrin occurrence reached a maximum, particularly in the lower Mississippi River, in water year 1964. (Oct. 1, 1963 - Sept. 30, 1964). Since then, endrin levels have decreased."

Occurrence of Endrin in Water

Sampling Methods. A sampling program was established by the Project on the main stem of the Mississippi and Atchafalaya Rivers, on eight of the tributaries to the Mississippi and at one estuarine location on the Louisiana coast to obtain data relative to endrin pollution of surface waters. (Figure 20 and Table 14).

The sampling techniques were designed to take into account the possibilities that endrin could be a suspended particle, adsorbed on suspended sediment particles, or be in solution. Sampling equipment and techniques were used that would take an unbiased sample of the water along with the suspended material which it contained.

Special samplers and other equipment required in conjunction with their use were designed at the St. Anthony Falls Hydraulic Laboratory in Minneapolis, Minnesota. Detailed information about their use and application can be found in reports published by the Federal Interagency Committee on Water Resources (38, 39, 40, 41, 42, 43).

Water samples from the streams were collected at cross-sectional points or as spatial composites. Procedures used resulted in the collection of samples from verticals located at the centroids of equal segments of discharge in the cross section of the rivers. The number of verticals sampled depended upon the size of the stream channel. For small streams, (Hatchie, Loosahatchie, and Wolf Rivers and Nonconnah Creek) either two or three verticals were sampled depending upon the stage. For the larger tributaries to the Mississippi and for the Atchafalaya River, five verticals were sampled at

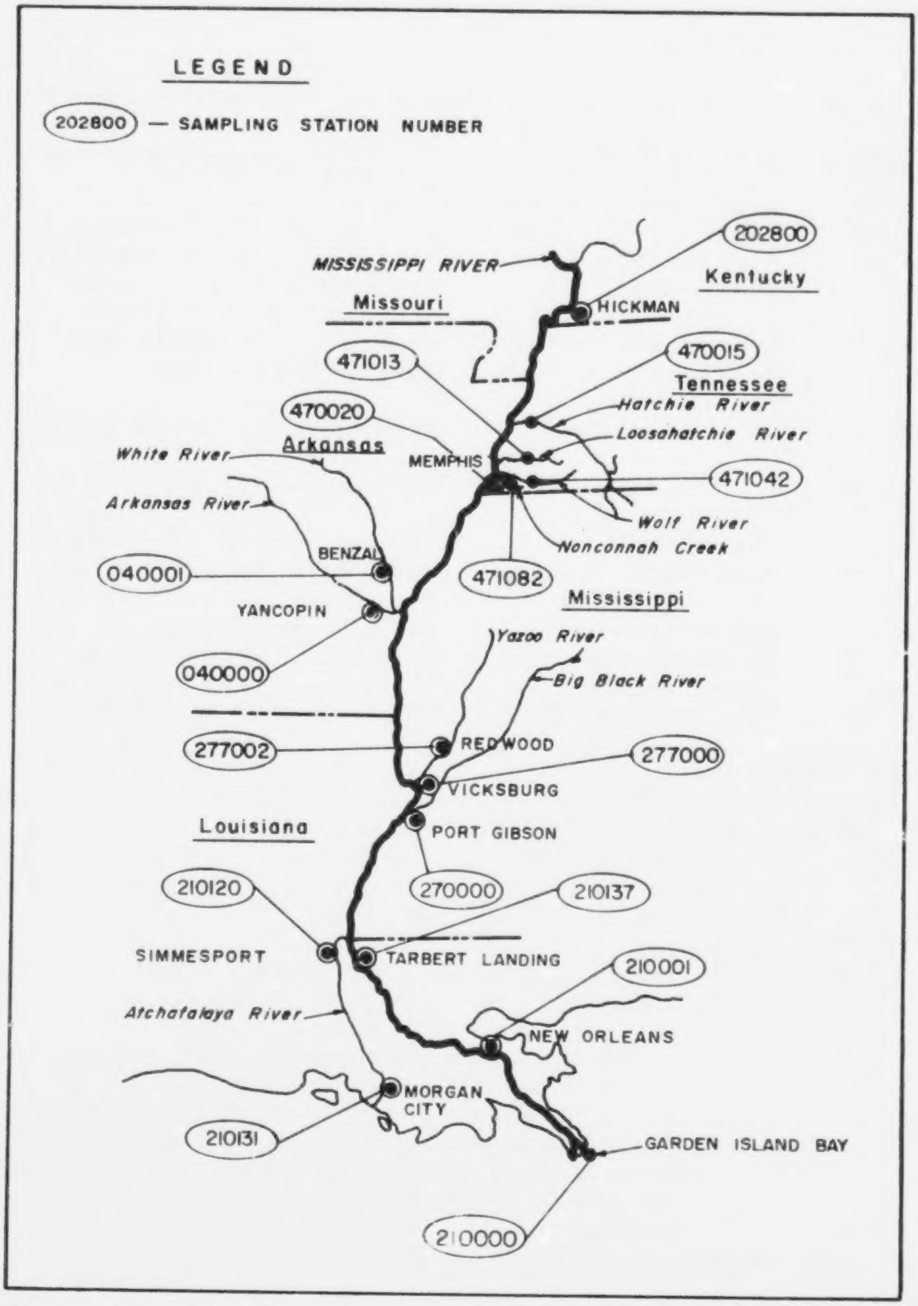
LEGEND
202800 — SAMPLING STATION NUMBER
MISSISSIPPI RIVER
202800
Kentucky
Missouri
HICKMAN
471013
470015
Tennessee
Hatchie River
470020
Loosahatchie River
Arkansas
White River
MEMPHIS
471042
Arkansas River
Wolf River
Nonconnah Creek
BENZAL
040001
471082
Mississippi
YANCOPIN
Yazoo River
040000
Big Black River
277002
REDWOOD
277000
VICKSBURG
Louisiana
PORT GIBSON
210120
270000
210137
SIMMESPORT
TARBERT LANDING
210001
Atchafalaya River
NEW ORLEANS
MORGAN CITY
210131
GARDEN ISLAND BAY
210000

Figure 20 — Location of sampling stations for endrin in water. Sampling stations numbers correspond to those given in Table 14.

Table 14. Sampling Stations for endrin.

Station number*	Station Name	Location
202800	Mississippi River	Hickman, Kentucky
470020	Mississippi River	Memphis, Tennessee
277000	Mississippi River	Vicksburg, Mississippi
210137	Mississippi River	Tarbert Landing, Louisiana
210001	Mississippi River	New Orleans, Louisiana
210120	Atchafalaya River	Simmesport, Louisiana
210131	Atchafalaya River	Morgan City, Louisiana
210000	Mississippi River Estuary	Garden Island Bay
470015	Hatchie River	State Hwy 54 (near Memphis, Tenn.)
471013	Loosahatchie River	Benjestown Road (Memphis, Tenn.)
471042	Wolf River	Thomas Street (Memphis,Tenn.)
471082	Nonconnah Creek	Horn Lake Road (Memphis, Tenn.)
04001	White River	Benzal, Arkansas
040000	Arkansas River	Yancopin, Arkansas
277002	Yazoo River	Redwood, Mississippi
270000	Big Black River	Port Gibson, Mississippi

* Station number are those used by STORET, the Federal Water Pollution Control Administration's computer program used for storing and retrieving water quality data.

all stages; and for the Mississippi River, eight were sampled at all river stages.

All samples taken on the Atchafalaya and Mississippi Rivers were individual point samples taken at the 10, 30, 50, 70 and 90 percent depths at five and eight verticals, respectively. This same sampling technique was used on the White, Arkansas, and Big Black Rivers during the first biweekly sampling period, but because of the relatively shallow depths of these streams, all subsequent samples were depth integrated at five verticals, i.e. the sampler was slowly lowered at a uniform rate to the bottom allowing it to gradually fill on the way. The Yazoo River samples were taken both by individual point samples and depth integration; the latter method was used during periods of low flow and the former during periods of high flow. All samples taken on the Wolf and Loosahatchie Rivers and on Nonconnah Creek were depth integrated at two verticals with an occasional single vertical sample being taken on Nonconnah Creek during extremely low water conditions. The point or depth integrated samples were composited except for once each quarter when point samples were analyzed individually.

The basic sampling frequency for all stations except the Wolf River was bimonthly; the Wolf River was sampled daily (excluding weekends) until September 1966 because endrin manufacturing wastes were continuously discharged directly into the Wolf River at Memphis for over a year. After September 1966, samples were taken once or twice a week. Generally, each sampling cycle on the main stem of the Mississippi was started at Hickman, Kentucky, and, inasfar as manpower availability and other considerations would allow, sampling times for the other stations were adjusted for flow time between stations. This procedure was designed so essentially the same water was sampled at all stations on the Mississippi River.

Special samples were taken for five consecutive days at each sampling station on the Mississippi and Atchafalaya Rivers three times a year when possible. These samples were taken during high, low and intermediate flow periods. Two series of special samples were also taken on the Yazoo River. These special samples consisted of collecting composite water samples for five consecutive days. During one of the five days, individual quart samples were retained from each point sample to be analyzed individually. In addition, surface samples were collected on some occasions at each vertical along with the regular point samples.

An estuarine station was established in Garden Island Bay in the Mississippi River estuary mainly for biological sampling.

No meaningful pattern of endrin concentration could be demonstrated among horizontal or vertical locations in the cross-section or between different depths and over limited time periods. At all stations there was a random distribution of endrin concentrations in the cross-section as shown in Figure 21. From this it was concluded that endrin was not present as a true solution. A statistical evaluation of the sampling design appears as Exhibit H in the Appendix.

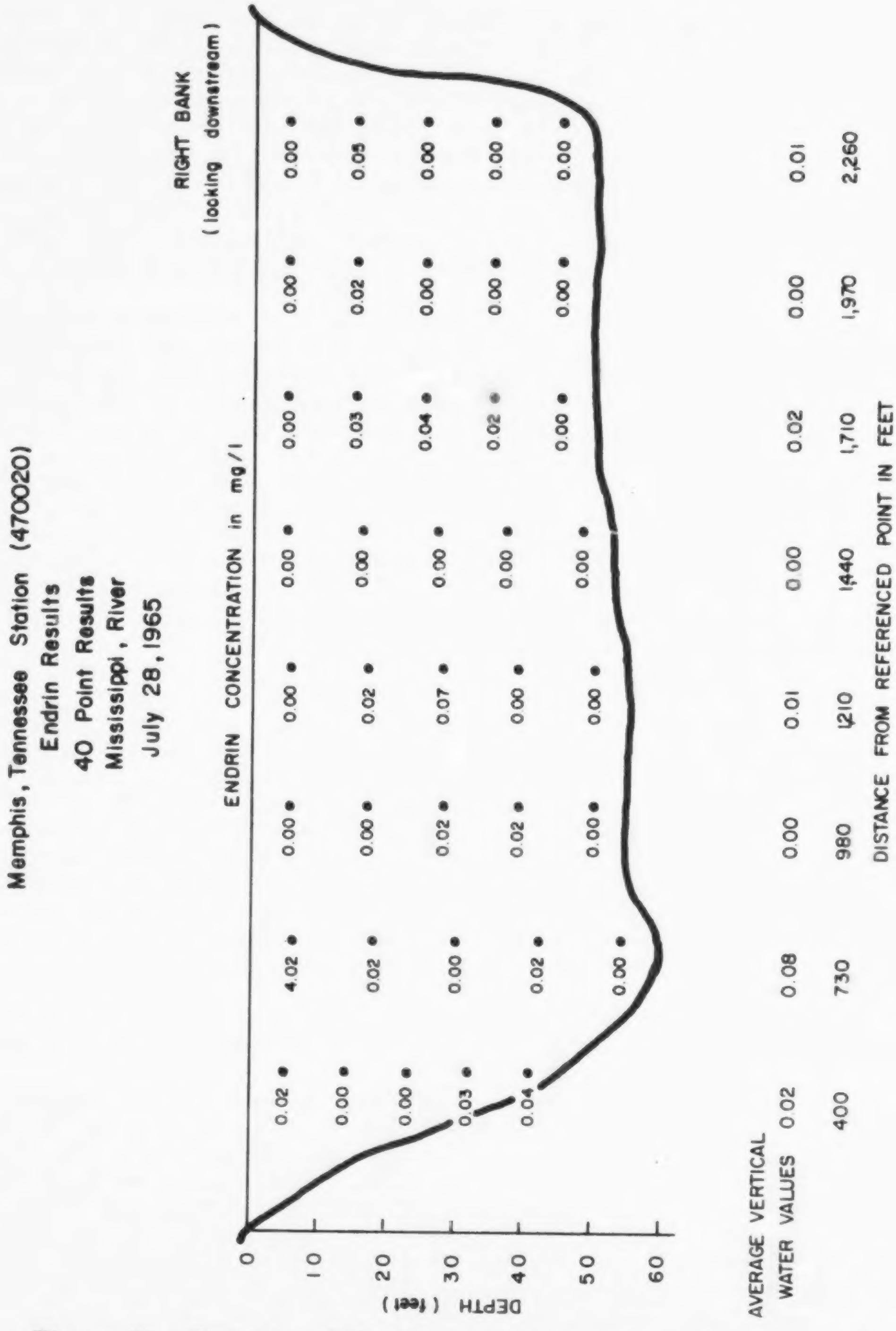

Figure 21 - Example of Endrin in River Cross Section.

Endrin in Waters of Mississippi and Atchafalaya Rivers. The period June 1965 through June 1966 was used for comparison of water samples from all river stations as this was the first period for which one full year's data were available for all main stem and tributary sampling stations, with the exception of the Garden Island Bay station. Table 15 summarizes the composite water sampling interval of June 10, 1965 through June 10, 1966 at the Hickman sampling station (the Project's most upstream sampling station on the Mississippi River) data from corresponding sampling intervals were selected for the downstream sampling stations in an attempt to adjust the sampling period for the flow time between stations.

Table 15 shows that mean endrin concentrations at the seven Mississippi-Atchafalaya River sampling stations were all of the same order of magnitude ranging from 0.04 to 0.07 µg/1. Thus it was concluded that endrin was relatively uniformly distributed in waters.

An attempt to obtain an endrin mass balance on the Mississippi and Atchafalaya Rivers was unsuccessful, thus endrin load data are not reported. Load data, if accurate, are extremely valuable; however, for the endrin data collect-

Table 15. Concentrations of endrin in waters of Mississippi and Atchafalaya Rivers for year, June 1965 through June 1966.

Sampling station	No. of samples	Inclusive sampling dates	Concentrations of endrin (µg/1)		
			Mean	Median	Range
Hickman	30	6/10/65-6/10/66	0.05	0.02	0.02 - 0.28
Memphis	33	6/15/65-6/15/66	0.04	0.03	0.02 - 0.23
Vicksburg	36	6/24/65-6/24/66	0.04	0.02	0.02 - 0.60
Tarbert Landing	38	6/26/65-6/30/66	0.06	0.04	0.02 - 0.39
New Orleans	38	6/29/65-6/29/66	0.07	0.03	0.02 - 0.33
Simmesport	34	6/26/65-6/26/66	0.06	0.04	0.02 - 0.36
Morgan City	33	6/29/65-6/29-66	0.04	0.04	0.02 - 0.19

ed they are meaningless because of the extremely small endrin concentrations and large discharges involved. Small differences in two concentrations, each within the limits of sampling and laboratory error, result in vast differences in calculated loads. Further, endrin concentrations, because of laboratory limits, of less than .02 µg/l were not quantitated, and these concentrations, though small, represent very significant loads of endrin when the volumes of water flowing in the Mississippi River are considered.

Relationship to Flow. Inasmuch as the fish kills in the Mississippi and Atchafalaya Rivers appeared to occur during periods of relatively low flow, endrin concentrations were compared to river flow on the Mississippi and Atchafalaya Rivers. The mean concentrations for five-day sampling periods was compared to the mean flow at the station for the period February 1965 through May 1966. Higher endrin concentrations usually occurred during periods of low or intermediate flow (Table 16). The New Orleans station produced the highest endrin concentrations, particularly during the intermediate and low flow periods of August and December 1965. The observation that endrin was found to occur in greater concentrations during conditions of low flow in the rivers is in line with the observations that the 1963-64 Mississippi River fish kills took place during comparable periods of low flow.

Endrin in Waters of Tributary Rivers. As with the sampling stations on the Mississippi and Atchafalaya Rivers, the period June 1965-June 1966 was used to compare composite water sampling data from all tributary river sampling stations (Table 17). Starting with a sampling interval of June 10, 1965 through June 10, 1966, at the Hickman sampling station on the Mississippi River, data from corresponding sampling intervals were selected for the tributary sampling stations to adjust the sampling period for the flow time between Hickman and the first tributary and between tributaries.

Mean endrin concentrations for the four major tributaries, White, Arkansas, Yazoo, and Big Black Rivers, (Table 17) were in the same range as the values obtained from main stem sampling stations (Table 15). No significant differences could be shown between these tributary river sampling stations and sampling stations on the main stem of the Mississippi River.

Mean endrin concentrations for the Memphis area tributaries, Wolf, Hatchie, and Loosahatchie Rivers and Nonconnah

Table 16. Relationship of endrin concentrations to flow in Mississippi and Atchafalaya Rivers, February 1965 through May 1966.

	Five-day mean flow (1000 cfs)	Five-day mean concentration (µg/l of endrin)	Dates of collection
Hickman	868	0.01	5/4-7/66
	460	0.05	2/22-3/1/65
	308	0.07	7/16-21/65
	198	0.05	11/10-14/65
Memphis	874	0.02	5/6-10/66
	712	0.08	2/13-18/65
	387	0.07	7/26-30/65
	216	0.06	11/16-20/65
Vicksburg	1041	0.03	5/9-13/66
	829	0.05	3/15-19/65
	256	0.03	8/4-11/65
	254	0.04	11/19-23/65
Tarbert Landing	784	0.02	5/12-16/66
	682	0.01	5/11-17/65
	259	0.04	7/26-30/65
	228	0.06	11/29-3/65
New Orleans	785	0.05	5/15-19/65
	646	0.04	3/23-27/66
	224	0.07	12/4-10/65
	208	0.10	8/12-18/65
Simmesport	377	0.07	5/16-20/66
	292	0.02	5/17-21/65
	128	0.03	8/2-6/65
	82	0.03	12/6-10/65

Table 17. Concentrations of endrin in waters of tributary rivers for year, June 1965 through June 1966.

Sampling station	No. of samples	Inclusive sampling dates	Concentrations of endrin (µg/l)		
			Mean	Median	Range
White	23	6/19/65-6/19/66	0.05	0.03	<0.02 - 0.24
Arkansas	22	6/19/65-6/19/66	0.03	0.02	<0.02 - 0.21
Yazoo	23	6/23/65-6/23/66	0.04	0.03	<0.02 - 0.16
Big Black	23	6/23/65-6/23/66	0.05	0.03	<0.02 - 0.27
Hatchie	30	6/15/65-6/15/66	0.35	0.17	<0.02 - 3.42
Loosahatchie	25	6/15/65-6/15/66	0.21	0.09	<0.02 - 1.58
Wolf	240	6/15/65-6/15/66	3.71	0.05	<0.03-112.17
Nonconnah	24	6/15/65-6/15/66	1.56	0.15	<0.02- 29.93

Creek, were higher than any of the other tributary samplings.

The Wolf River with a mean concentration of 3.71 µg/1 of endrin had the highest endrin concentration of any of the streams sampled. The Velsicol Endrin manufacturing plant is located on the Wolf River drainage and was a known contributor of endrin wastes to this stream during most of 1965 (see Chapter 4 - Sources of Endrin Pollution).

Nonconnah Creek has a mean concentration of 1.56 µg/1 and was the second highest in the study area; several industries, including one pesticide formulator, are located on its banks, however, because of its small average discharge of 40 cfs, it cannot be considered a significant source of endrin to the Mississippi River.

The Hatchie River has a higher mean concentration of endrin than the Mississippi River and other major tributaries. This might possibly be attributed in part to surface runoff from the Velsicol land-fill dump in Hardeman County, Tennessee. A study evaluating the possible contamination of surface and ground waters from this dump was made by the U. S. Geological Survey. Results are discussed in Chapter 6.

Endrin in agricultural runoff was also considered to be a source of endrin pollution in the Loosahatchie River and the other three Tennessee tributaries discussed above.

Endrin in Estuarine areas. Six water samples were obtained from the Garden Island Bay sampling station in the Mississippi River estuary. The mean endrin concentration of these samples taken during the period August 31, 1965 through June 29, 1966 was 0.04 µg/1, and ranged from 0.02-0.07 µg/1. These values are within the same general range of concentrations obtained at the sampling stations on the Mississippi River (Table 15).

Trends in Endrin Concentrations. A comparison of mean endrin concentrations by months in the tributary rivers (Table 17) as well as those on the main stem of the Atchafalaya and Mississippi Rivers (Table 15) did not reveal any definite seasonal trends. A comparison of mean yearly endrin concentrations showed a downward trend in the tributary rivers (Table 18). The Wolf River showed the most pronounced decline in endrin concentrations from 1965 to 1966 because the Wolf River interceptor sewer of the City of Memphis was closed from January to December and, during this period, sewage

Table 18. Mean concentrations of endrin (µg/1) in tributary rivers by months. The figures in parentheses represent the number of composite water samples.

	Time of year												Mean for year
	January	February	March	April	May	June	July	August	September	October	November	December	
Hatchie													
1965	- (-)	- (-)	- (-)	- (-)	- (-)	0.55 (2)	0.18 (4)	1.17 (4)	0.03 (2)	0.23 (2)	0.19 (2)	0.46 (2)	0.45 (18)
1966	0.08 (2)	0.85 (2)	0.18 (3)	0.01 (2)	0.04 (2)	0.00 (2)	0.04 (3)	0.01 (2)	0.00 (2)	0.03 (2)	0.03 (3)	0.04 (1)	0.11 (26)
1967	- (-)	- (-)	- (-)	- (-)									- (-)
Loosahatchie													
1965	- (-)	- (-)	0.35 (2)	0.58 (3)	0.14 (2)	0.29 (2)	0.16 (2)	0.37 (3)	0.30 (2)	0.15 (2)	0.09 (2)	0.08 (2)	0.26 (22)
1966	0.03 (2)	0.19 (2)	0.02 (2)	0.83 (2)	0.06 (2)	0.00 (1)	0.09 (3)	0.00 (2)	0.00 (2)	0.00 (2)	1.63 (2)	0.03 (3)	0.23 (25)
1967	- (-)	- (-)	- (-)	- (-)									- (-)
Wolf													
1965	1.55(10)	0.56 (19)	0.60(22)	0.51(22)	2.03(22)	6.06(22)	18.86(21)	6.34(22)	2.72(20)	4.89(19)	2.99 (12)	0.63 (20)	4.15 (231)
1966	0.28(19)	0.22 (19)	0.55(23)	0.73(21)	0.31(21)	0.30(21)	0.22(19)	0.16(16)	0.35 (9)	0.14 (9)	0.19 (9)	0.08 (7)	0.33 (193)
1967	1.37 (5)	0.21 (4)	0.24 (4)	0.26 (4)									0.57 (17)
Nonconnah Cr.													
1965	- (-)	- (-)	0.21 (2)	0.31 (2)	0.16 (2)	15.22 (2)	1.04 (3)	0.29 (2)	0.13 (2)	0.27 (2)	1.19 (2)	0.25 (2)	1.86 (21)
1966	0.05 (2)	0.18 (2)	0.00 (1)	0.16 (2)	0.08 (2)	0.46 (2)	0.19 (3)	0.18 (2)	0.00 (2)	0.13 (2)	0.44 (2)	0.03 (2)	0.16 (24)
1967	- (-)	- (-)	- (-)	- (-)									- (-)
White													
1965	- (-)	- (-)	- (-)	- (-)	0.01 (2)	- (-)	0.10 (2)	0.04 (2)	0.07 (2)	0.05 (2)	0.15 (2)	0.00 (2)	0.05 (14)
1966	0.10 (2)	0.03 (2)	0.01 (3)	0.00 (2)	0.00 (1)	0.00 (2)	0.15 (2)	0.00 (2)	0.00 (2)	0.01 (2)	0.00 (2)	0.00 (1)	0.03 (23)
1967	- (-)	- (-)	- (-)	- (-)									- (-)
Arkansas													
1965	- (-)	- (-)	- (-)	- (-)	0.01 (2)	- (-)	0.21 (1)	0.02 (2)	0.07 (2)	0.04 (2)	0.05 (2)	0.00 (2)	0.04 (13)
1966	0.04 (2)	0.04 (2)	0.01 (3)	0.00 (2)	0.00 (1)	0.00 (2)	0.25 (3)	0.00 (2)	0.00 (2)	0.00 (2)	0.00 (2)	0.01 (2)	0.04 (25)
1967	- (-)	- (-)	- (-)	- (-)									- (-)
Yazoo													
1965	- (-)	- (-)	- (-)	0.07 (6)	0.04 (2)	0.05 (1)	0.11 (1)	0.11 (2)	0.04 (1)	0.02 (2)	0.04 (3)	0.00 (1)	0.05 (19)
1966	0.02 (2)	0.07 (2)	0.03 (3)	0.04 (2)	0.02 (1)	0.00 (2)	0.11 (2)	0.00 (2)	0.00 (2)	0.02 (2)	0.02 (2)	0.03 (1)	0.03 (23)
1967	0.02 (3)	0.03 (2)	0.00 (1)	0.00 (1)									0.01 (7)
Big Black													
1965	- (-)	- (-)	- (-)	- (-)	0.04 (2)	0.27 (1)	0.12 (1)	0.09 (2)	0.03 (1)	0.07 (2)	0.02 (3)	0.00 (1)	0.06 (13)
1966	0.13 (2)	0.02 (2)	0.00 (3)	0.03 (2)	0.00 (1)	0.00 (2)	0.25 (2)	0.02 (1)	0.00 (2)	0.04 (2)	0.05 (2)	0.00 (1)	0.05 (22)
1967	- (-)	- (-)	- (-)	- (-)									- (-)

containing Velsicol's wastes was discharged to the Wolf River. When the interceptor was opened in late December 1965, Velsicol wastes were no longer discharged to the Wolf River. The apparent decline in endrin concentrations in the White, Yazoo and Big Black Rivers from 1965 to 1966 probably reflects a decrease in the agricultural use of endrin.

The main stem data does not show the same downward trend between 1965 and 1966 at all sampling stations (Table 19) although the nine months of data for 1967 do show a decline in endrin pollution.

Endrin in River Bed Materials

Sampling Methods. The sampling regimen for bed load (bottom sediments) paralleled that of the water sampling. Samples were taken at the same stations (Figure 20 and Table 14), and normally at the same frequencies as were the water samples. Samples were analyzed as described in the Appendix, Exhibit B.

The sampling design provided two to three individual samples per sampling date from the Memphis area tributaries, five from the larger tributaries and the Atchafalaya River, and eight from the Mississippi River sampling stations. These samples were analyzed individually and the mean endrin concentrations for each cross-section were obtained by arithmetically averaging the individual values. Bed load sediments were not taken at equilateral points across a stream bottom but rather at the bottom of verticals located laterally at centroids of equal segments of discharge. This sampling design was chosen to give equal weight, on the basis of discharge, to water samples. The method indirectly weights the velocity of the stream, since discharge is a function of velocity and cross-sectional area. Bed sediments defined as "bed load" move along the bed of a stream at a velocity largely dependent upon the velocity of the moving water; consequently, the sampling method also tends to give equal weight to these moving bottom sediments, and allows the use of an arithmetic average of individual values to obtain the mean of a parameter associated with these sediments.

Endrin in River Bed Samples. Table 20 presents a summary of the mean endrin concentrations and ranges for each river sampling station for a period of approximately one year, the period during which bed samples were collected.

Table 19. Mean concentration of endrin (μg/l) in Mississippi and Atchafalaya Rivers by months. The figures in parentheses represent the number of composite water samples.

	Time of year												Mean for Year
	January	February	March	April	May	June	July	August	September	October	November	December	
Hickman													
1965	- (-)	0.05 (4)	0.01 (2)	0.03 (2)	0.06 (1)	0.00 (1)	0.06 (4)	0.02 (2)	0.04 (2)	0.02 (2)	0.04 (5)	0.02 (1)	0.03 (26)
1966	0.06 (1)	0.14 (2)	0.18 (2)	0.00 (2)	0.01 (6)	0.01 (2)	0.05 (2)	0.01 (2)	0.00 (2)	0.00 (1)	0.01 (3)	0.00 (1)	0.04 (26)
1967	0.01 (2)	0.02 (1)	0.00 (1)	0.01 (2)	0.02 (2)	0.03 (3)	0.00 (2)	0.01 (2)	0.01 (2)				0.01 (17)
Memphis													
1965	- (-)	0.08 (5)	0.00 (1)	0.48 (2)	0.04 (1)	0.03 (1)	0.06 (6)	0.04 (2)	0.00 (1)	0.10 (3)	0.05 (6)	0.00 (1)	0.08 (29)
1966	0.06 (2)	0.06 (1)	0.00 (1)	0.03 (3)	0.01 (6)	0.00 (1)	0.06 (3)	0.00 (2)	0.00 (2)	0.01 (2)	0.00 (2)	0.00 (2)	0.02 (27)
1967	0.00 (2)	0.03 (3)	0.00 (1)	0.00 (1)	0.02 (2)	0.34 (3)	0.05 (2)	0.00 (2)	0.00 (2)				0.07 (18)
Vicksburg													
1965	- (-)	- (-)	0.04 (5)	0.02 (1)	0.03 (2)	0.00 (2)	- (-)	0.03 (7)	0.05 (1)	0.04 (2)	0.04 (6)	0.00 (1)	0.03 (27)
1966	0.02 (3)	0.02 (3)	0.00 (2)	0.30 (2)	0.02 (7)	0.00 (1)	0.06 (2)	0.03 (4)	0.00 (2)	0.02 (2)	0.07 (2)	0.00 (1)	0.04 (31)
1967	0.00 (3)	0.00 (2)	0.00 (1)	0.00 (1)	0.03 (2)	0.10 (2)	0.00 (2)	0.01 (2)	- (-)				0.04 (15)
Tarbert Landing													
1965	0.02 (1)	0.10 (2)	0.01 (2)	0.02 (2)	0.00 (6)	0.05 (3)	0.09 (6)	0.10 (3)	0.05 (3)	0.07 (1)	0.06 (4)	0.06 (4)	0.05 (37)
1966	0.06 (2)	0.03 (2)	0.01 (2)	0.07 (2)	0.01 (6)	0.00 (2)	0.12 (2)	0.03 (2)	0.00 (3)	0.04 (2)	0.00 (2)	- (-)	0.03 (27)
1967	0.00 (2)	2.26 (2)	0.00 (2)	0.00 (2)	0.03 (1)	0.09 (2)	- (-)	0.02 (3)	0.29 (1)				0.34 (15)
New Orleans													
1965	- (-)	- (-)	0.04 (5)	- (-)	0.05 (1)	0.03 (4)	0.04 (2)	0.10 (5)	0.14 (3)	0.00 (1)	0.14 (3)	0.07 (6)	0.07 (30)
1966	0.11 (3)	0.12 (2)	0.01 (2)	0.07 (2)	0.03 (6)	0.00 (3)	0.10 (2)	0.03 (2)	0.00 (2)	0.02 (2)	0.00 (3)	0.00 (2)	0.04 (31)
1967	0.02 (2)	0.01 (2)	0.02 (1)	0.02 (2)	0.04 (2)	0.15 (1)	0.20 (1)	0.00 (1)	0.10 (1)				0.05 (13)
Simmesport													
1965	0.00 (1)	0.03 (2)	0.00 (2)	0.04 (2)	0.02 (6)	0.02 (2)	0.04 (2)	0.08 (6)	0.20 (2)	0.04 (2)	0.04 (1)	0.02 (6)	0.04 (34)
1966	0.12 (2)	0.09 (2)	0.01 (2)	0.03 (2)	0.08 (6)	0.02 (1)	0.57 (1)	0.02 (2)	0.00 (3)	0.05 (2)	0.00 (2)	0.00 (1)	0.06 (26)
1967	0.00 (2)	0.01 (2)	0.00 (2)	0.00 (1)	0.02 (2)	0.08 (2)	0.00 (1)	0.01 (2)	0.00 (2)				0.01 (16)
Morgan City													
1965	- (-)	- (-)	- (-)	- (-)	- (-)	0.05 (6)	0.04 (2)	0.03 (5)	0.06 (3)	0.06 (1)	0.03 (2)	0.03 (5)	0.04 (24)
1966	0.06 (2)	0.10 (2)	0.00 (2)	0.04 (1)	0.02 (6)	0.02 (2)	0.00 (1)	0.00 (2)	0.21 (1)	0.00 (2)	0.01 (3)	0.00 (1)	0.03 (25)
1967	0.03 (2)	0.00 (2)	0.02 (1)	0.00 (2)	0.03 (2)	0.00 (2)	0.01 (2)	0.00 (1)	0.20 (1)				0.02 (15)

Table 20. Summary of endrin concentrations in bed materials for one year.

River and Sampling Station	No. of Sampling Days	Inclusive Sampling Dates	Concentrations of endrin (μg/kg, dry weight)	
			Mean	Range
Mississippi River at Hickman	23	6/2/65-6/2/66	4.59	<0.16 - 38.71
Mississippi River at Memphis	25	6/3/65-6/10/66	3.20	<0.16 - 22.25
Mississippi River at Vicksburg	25	6/28/65-6/13/66	0.13	<0.16 - 1.31
Mississippi River at Tarbert Lndg.	28	6/30/65-6/22/66	0.73	<0.16 - 7.29
Mississippi River at New Orleans	26	6/16/65-6/21/66	2.13	<0.16 - 6.92
Atchafalaya River at Simmesport	26	6/18/65-6/24/66	0.38	<0.16 - 2.62
Atchafalaya River at Morgan City	23	6/22/65-6/8/66	0.57	<0.16 - 3.59
White River at Benzal	24	7/1/65-6/21/66	5.25	<0.16 - 123.80
Arkansas River at Yancopin	23	7/18/65-6/22/66	5.47	<0.16 - 123.60
Yazoo River at Redwood	23	6/29/65-6/23/66	1.77	<0.16 - 33.40
Big Black River at Port Gibson	22	6/30/65-6/23/66	1.68	<0.16 - 32.20
Wolf River at Thomas Street	157	7/27/65-6/30/66	1281.00	<0.16 -6266.00
Loosahatchie River at Memphis	23	8/6/65-6/17/66	61.47	0.47 - 431.00
Hatchie River at Near Memphis	26	7/27/65-6/21/66	50.40	<0.16 - 473.00
Nonconnah Creek at Memphis	20	7/30/65-6/17/66	29.37	2.00 - 139.00

Each mean of endrin concentrations in water shown in Table 19 represents the average of one year of arithmetically composited cross-sectional water values obtained as described above. Individual cross-sectional values of endrin in sediment as well, as their means, demonstrated more variability than did the corresponding water concentrations. This variability can in part be attributed to the variability in composition of the sediments themselves.

It appears that there was a parallel between endrin concentration in water and bottom sediments. The Memphis area tributaries, for example, had higher concentrations of endrin in sediments than the sediments of the other tributaries and the Atchafalaya and Mississippi Rivers. The Wolf River sediment values for endrin, like those of the water, were the highest found at all stations.

The average endrin concentrations of the bed materials was approximately 200 times higher than the average water concentrations (averaging all values for one year).

Endrin in Separated Bed Sediments. Selected Bed sediment samples from all sampling stations were subjected to a fractionating technique in which the sediments were roughly separated into "sand", "silt-clay", and "clay" fractions. These individual fractions were then analyzed for endrin. Concentrations of endrin were highest in the "clay" fraction.

Endrin in Finished Water Supplies

During 1964 and 1965, the Interstate Carrier Branch, Division of Environmental Engineering and Food Protection, U. S. Public Health Service, obtained water samples for endrin anaylsis from six water plants (Figure 22) using Mississippi River water. The results of these samples analyzed by the Interstate Carrier Branch are summarized in Table 21. Some samples from each of the six finished water supplies obtained during 1964 contained endrin equal to or in excess of 0.1 µg/l. All finished water samples from these six supplies contained less than 0.1 µg/l during 1965. Raw water samples were obtained during both years from two supplies (Figure 22). Three of five samples from one supply contained endrin in excess of 0.1 µg/l during 1964. Samples collected during 1965 from these two supplies contained less than 0.1 µg/l endrin. The range of endrin concentrations in these water samples was significantly less than recommended limits established by the U. S. Food and Drug Administration from a health standpoint (44).

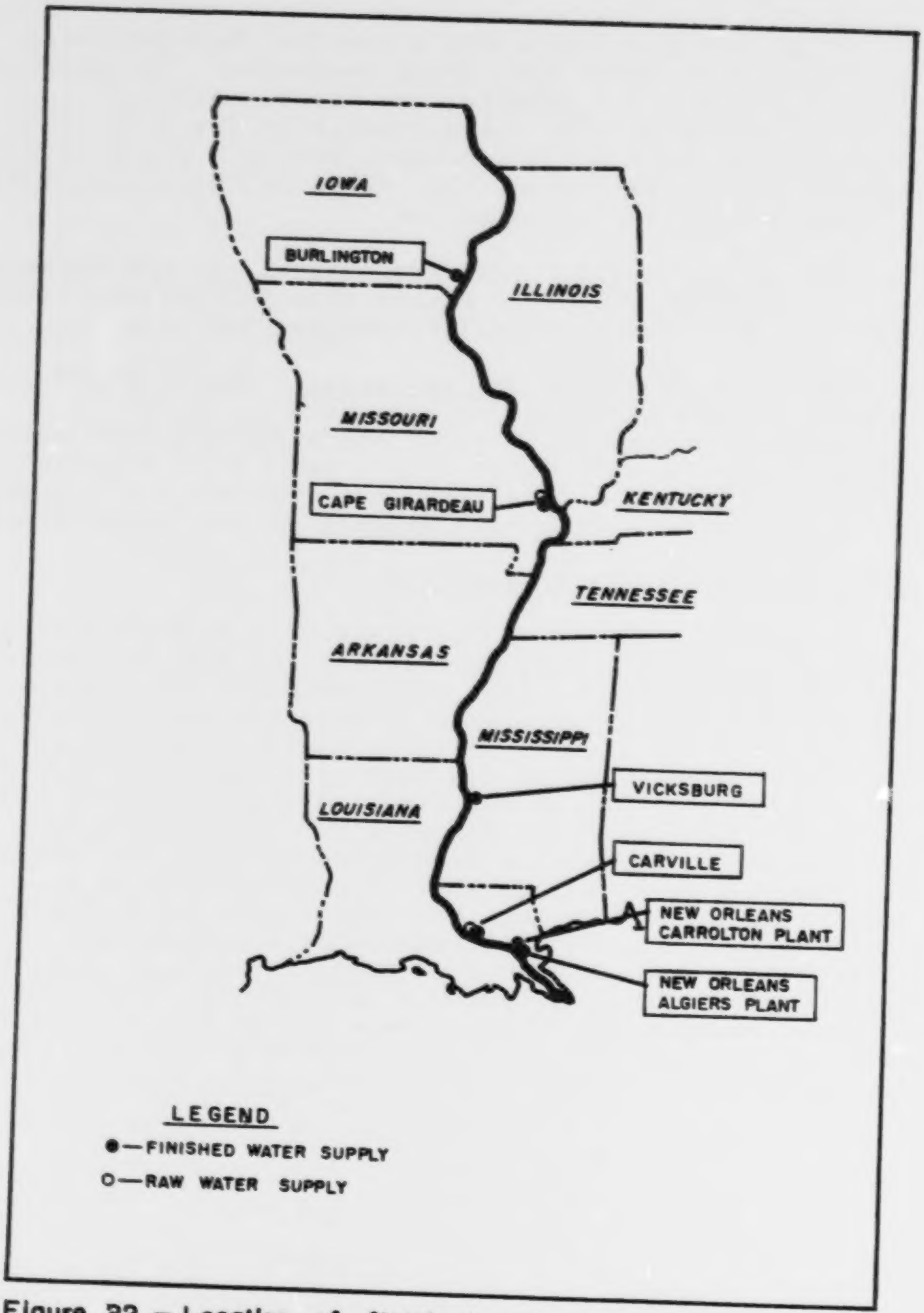
IOWA
BURLINGTON
ILLINOIS
MISSOURI
CAPE GIRARDEAU
KENTUCKY
TENNESSEE
ARKANSAS
MISSISSIPPI
VICKSBURG
LOUISIANA
CARVILLE
NEW ORLEANS CARROLTON PLANT
NEW ORLEANS ALGIERS PLANT
LEGEND
●—FINISHED WATER SUPPLY
○—RAW WATER SUPPLY

Figure 22 – Location of finished and raw water supplies sampled for endrin.

Table 21. Concentration of endrin in finished water supplies.

Water supply	Total number of samples		Number of samples endrin concentrations >0.1 µg/l *		Maximum concentration of endrin (µg/l) *	
	1964	1965	1964	1965	1964	1965
Finished water						
Burlington, Iowa	8	5	1	0	0.50	-
Cape Girardeau, Mo.	19	12	4	0	0.25	-
Vicksburg, Miss.	35	13	7	0	0.40	-
Carville, La.	28	9	4	0	1.00	-
New Orleans, La.:						
Carrolton Plant	20	6	4	0	0.12	-
Algiers Plant	19	6	2	0	0.17	-
Raw Water						
Cape Girardeau, Mo.	5	1	3	0	0.42	-
Carville, La.	4	2	0	0	-	-

* On wet weight basis

CHAPTER 6

EFFECT OF ENDRIN ON ENVIRONMENT

Fish Populations

A survey of the fish populations in the Mississippi and Atchafalaya Rivers was initiated in January 1966 in order to determine the effects of environmental changes on fish populations. Specifically, information was collected on the relative abundance of fish, their size, distribution, and species composition. Data are presented in Exhibit I of the Appendix on the fish populations sampled during twenty-four sampling periods with experimental gill nets, trammel nets and hoop nets at seven sampling stations for a three year period ending in December 1968.

Apparently, within this period, the fish population in the Lower Mississippi River Basin was able to recover from any effects of the 1963-64 fish kills. How great an effect endrin had on the fish populations is not known inasmuch as no data on the normal population in the rivers were available. However, examination of the length frequency data of the fish captured showed an apparent paucity of fish in the larger size groups of the more long lived species.

For purposes of determining environmental changes induced by endrin pollution in the rivers, fish populations sampling was one of the most valuable and indispensable tools. Fish populations are extremely sensitive to water quality changes and, in fact, are continuously reflecting the sum total or combined effect of many water quality parameters and pollutants. The fish population data collected will serve as an extremely valuable base to determine future effects of environmental and hydrological changes on the fish populations and thus on the beneficial use of the water.

Occurrence of Endrin in Fish Blood

Sampling Methods. Determination of the concentration of endrin in the blood of freshwater fishes collected from the Mississippi and Atchafalaya Rivers and from saltwater fishes collected from Redfish Bay, an estuary of the Mississippi River, was initiated in the spring of 1965 in order to evaluate the degree of contamination of fish with endrin. Because of their occurrence at all the freshwater sampling stations and because they are an important component of the fish population in the Lower Mississippi River Basin, smallmouth buffalo, channel catfish, and gizzard shad were selected as the primary species from which to collect blood samples. Blood samples were collected from a maximum of five individuals of each species obtained at seven freshwater sampling stations (Figure 23). If the primary species were not available, largemouth buffalo were collected in the absence of smallmouth buffalo and blue catfish in the absence of channel catfish.

Prior to October 1965, blood samples were collected on a monthly basis from freshwater fish obtained from commercial fishermen's catches; however, after October 1965 when the fish survey was initiated, they were obtained during regular scheduled fish population sampling operations at approximately six week intervals. After September 1966, the sampling frequency was reduced to four times a year. Prior to October 1965, when fish were obtained from commercial fishermen, one of the sampling stations on the Mississippi River was above the Wolf River at Memphis, Tennessee; however, this station was abandoned and fish were obtained during the regular fish populations sampling operations at Tunica, 40 river miles downstream from Memphis. All other freshwater sampling stations prior to September 1966 corresponded to the fish survey sampling stations; however, after this date blood samples were collected from fish obtained at only the Hickman, Vicksburg, Luling, and Morgan City sampling stations.

Blood samples were collected from saltwater fish which were caught at the Garden Island Bay sampling station (Figure 23) with a 16 foot otter trawl. Blood samples were taken from a maximum of five individuals of largescale menhaden, sand seatrout, (_Cynoscion arenarius_) and Atlantic croaker (_Micropogon undulatus_) collected at the same approximate time intervals as the freshwater fish. Prior to February 1966, only largescale menhaden were collected for blood samples.

Blood samples were obtained at the fish collecting site from live specimens. The fish from which a blood sample was obtained was first wiped clean of dirt and surface moisture. If it was a scale fish, the scales were removed from the tail posterior to the anal fin and then the fish was wiped clean again. The tail was severed and a minimum of 10 drops (approximately 1 ml) of blood was collected in a vial

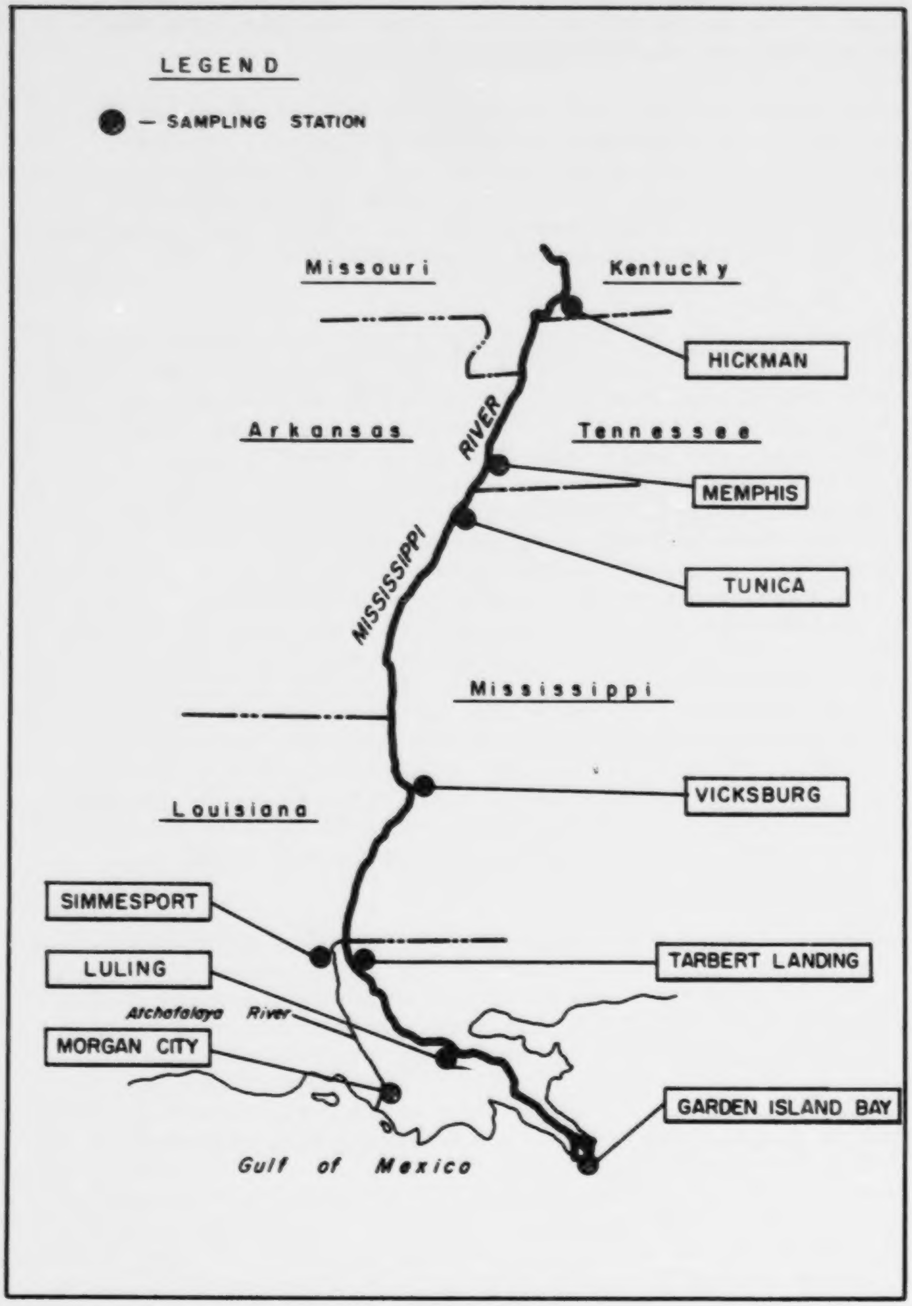
LEGEND
● — SAMPLING STATION
Missouri
Kentucky
HICKMAN
Arkansas
Tennessee
RIVER
MEMPHIS
MISSISSIPPI
TUNICA
Mississippi
VICKSBURG
Louisiana
SIMMESPORT
TARBERT LANDING
LULING
Atchafalaya River
MORGAN CITY
GARDEN ISLAND BAY
Gulf of Mexico

Figure 23 — Location of sampling stations at which fish were collected for determination of endrin content in blood.

which was immediately tagged and placed on dry ice. A new 20 ml glass vial with an aluminum foil liner in the lid and prerinsed with a solvent was always used.

Unless otherwise noted, all blood samples weighed at least 0.5 gram and were analyzed by Woodson-Tenant Laboratories, Memphis, Tenn. All weights are reported as wet weight. The blood from each individual fish was analyzed separately and all mean values reported represent the weighted arithmetic average of the number of blood samples in the grouping.

Occurrence of Endrin in Freshwater Fish. The mean concentration of endrin in the blood of 341 buffalo fish collected at all sampling stations and during all sampling periods was .02 µg/g (Table 22), a concentration less than the minimum levels of .23 µg/g and .10 µg/g found to be indicative of acute intoxication in channel catfish and gizzard shad, respectively. Critical levels indicative of acute intoxication from endrin were found to range from 0.23 to 0.28 µg/g for channel catfish and 0.10 to 0.14 µg/g for gizzard shad (see Chapter 3 - Toxicity of Endrin). Since endrin concentrations in blood of apparently healthy catfish and shad, taken at times from all stations, exceeded these critical endrin concentration levels, it is concluded that at least some individuals of these two species had developed a tolerance to endrin. This is supported by like conclusions of Ferguson et al., cited in Chapter 3, Toxicity of Endrin. Concentrations of endrin in the blood were the highest during June and July of 1965 and February of 1966. Mean concentrations of endrin in the blood declined after March 1966, as compared to most previous sampling periods.

The reliance which can be placed on the mean concentrations of endrin in the blood of fish as an indication of endrin contamination of the aquatic environment depends on the number of blood samples analyzed. An experiment was conducted to determine the variability of blood samples collected under field conditions. The blood from each of nine smallmouth buffalo fish collected June 8, 1966 at the Luling sampling station was divided into two samples and analyzed separately. The mean endrin concentration of the 18 samples was 0.048 µg/g while individual determinations ranged from 0.02 to 0.15 µg/g. An analysis of variance was performed on these data (Table 23). No significant differences in endrin concentration of the blood from different fish could be detected (F = 2.8571 with 8 and 9

Table 22. Mean concentration of endrin in blood of buffalo fish expressed in µg/g. The figure in parentheses represents the number of blood samples.

Sampling periods	Sampling station								All Stations
	Hickman	Memphis	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
4/12-30/65	.03(14)	.03 (2)	-	.02 (4)	-	-	.05 (5)	-	.03(25)
5/6-28/65	-	-	-	-	.02 (3)	-	.05 (5)	-	.04 (8)
6/11-18/65	-	-	-	-	.04 (5)	.08 (4)	-	-	.06 (9)
7/9-29/65	.02 (1)	-	-	.07 (4)	.02 (1)	.03 (5)	.07 (7)	.01 (3)	.05(21)
8/5-26/65	.01 (5)	.00 (1)	-	.05 (4)	.02 (5)	.00 (5)	.04 (4)	.01 (2)	.02(26)
9/13-22/65	.00 (1)	-	-	.03 (2)	.01 (2)	-	.00 (2)	-	.01 (7)
10/11-30/65	-	-	.03 (1)	-	.01 (5)	.01 (5)	.03 (2)	.03 (2)	.02(15)
11/10-12/15,65	.01 (1)	-	-	.01 (5)	.00 (3)	-	.03 (4)	.00 (2)	.01(15)
1/17-2/4,66	.00 (5)	-	.00 (3)	.01 (5)	.01 (5)	.02 (4)	.01 (5)	.00 (4)	.01(31)
2/25-3/19,66	.09 (5)	-	.09 (4)	.03 (5)	.02 (5)	.03 (5)	.04 (5)	.01 (3)	.05(32)
4/21-5/10,66	.01 (5)	-	.01 (5)	.01 (5)	.00 (5)	.03 (5)	.01 (5)	.01 (5)	.01(35)
6/6-24/66	.00 (5)	-	.03 (5)	.01(10)	.00 (5)	.05(10)	-	.00 (5)	.02(40)
7/11-29/66	.00 (5)	-	.00 (5)	.00 (5)	.00 (3)	.03 (5)	.00 (5)	.00 (5)	.01(33)
8/22-9/9,66	.00 (5)	-	.01 (4)	.00 (5)	.00 (5)	.00 (5)	.00 (5)	.00 (5)	.00(34)
11/15-12/10,66	.00 (1)	-	.02 (3)	.01 (5)	-	.02 (1)	-	-	.01(10)
All periods	.02(53)	.01 (3)	.02(30)	.02(59)	.01(52)	.03(54)	.03(54)	.01(36)	.02(341)

Note: Sampling at the Memphis, Tennessee station was stopped in September 1965. Sampling at the Tunica, Mississippi station, approximately 43 river miles below Memphis, was started in October 1965.

Table 23. Analyses of variance of endrin concentrations of duplicate blood samples from nine buffalo fish collected at Luling sampling station, June 8, 1966.

Sources of variation	Degrees of Freedom	Sum of Squares	Mean square
Total	17	.0234	.0013
Individual fish	8	.0167	.0020
Individual determinations	9	.0067	.0007

degrees of freedom: P >.05). The mean square for total variation (.0013) was used as an estimate of the variance of the individual blood samples which would be collected from a series of smallmouth buffalo fish under field conditions by unrestricted random sampling. If individual blood samples were collected from two fish, the standard error of the mean would be .025. Assuming a normal distribution, the 95 percent confidence limits of the mean endrin concentration of .048 µg/g would be from 0 to .375 µg/g. Confidence limits based on 4 samples would be from 0 to .105 µg/g, while those based on 5 samples would be from .004 to .092 µg/g, those based on 7 samples would be from .017 to .079 µg/g and those based on 10 samples would be from .023 to .073 µg/g.

It is obvious that the use of blood samples from only a few buffalo fish as indication of endrin contamination at a given sampling station and period could be misleading. Not too much reliance should be placed on estimates of mean concentration of endrin in the blood for a sampling period at a given sampling station where only 2 or 3 samples from individual fish are involved. If the estimate of variability is fairly approximate, then the mean values given in Table 22 would be less than the minimum level of .10 µg/g found indicative of acute intoxication in gizzard shad where the mean concentration of endrin in the blood is equal to or less than .05 µg/g and at least 5 buffalo fish were sampled. From the examination of the data and other data not presented in this report, the variance of such data appears to be correlated with the mean. Therefore, confidence limits based on one size mean should not be used directly as a guide to confidence limits for other size means. Also, undoubtedly the variability of such data for other species of fish and for smallmouth buffalo fish under other conditions could be considerably different.

The mean concentration of endrin in the blood of 253 gizzard shad collected at all sampling stations and during all sampling periods was .04 µg/g (Table 24). Concentrations were the highest during June, July, and August of 1965, February and March of 1966, and December of 1966. However, the abnormally high mean concentration during December of 1966 of .20 µg/g for all stations was due to the high concentration of .65 µg/g encountered in the blood of fish from the Tunica sampling station. Mean values from all of the other sampling stations during the same sampling period did not exceed .01 µg/g. The data for this sampling period at the Tunica sampling station was extremely variable and the 95 percent confidence limits assuming a normal distribution are .65 ± 1.33 µg/g. Therefore, not too much reliance can be placed on this one estimate. No reason is known why an abnormally high concentration of endrin should have occurred at the Tunica sampling station during that sampling period.

Eight of the mean values obtained at individual sampling stations for individual sampling periods exceeded the minimum value of .10 µg/g found to be indicative of acute intoxication from endrin in gizzard shad. However, only three of these means were based on samples from more than 3 fish. The variability of the concentrations of endrin in the blood of the gizzard shad was greater than that for buffalo fish. Therefore, less reliance can be placed on estimates of mean concentrations of endrin in the blood of gizzard shad than on estimates of mean concentrations for other species of fish based on the same sample sizes. No time trends in the concentration of endrin in the blood of gizzard shad were apparent. Mean concentration for all sampling periods was much higher at the Tunica sampling station than any of the other sampling stations. However, this was due mainly to high concentrations obtained during 3 sampling periods out of the 9 sampling periods for which data were available at the Tunica sampling station. Tunica is the closest sampling station downstream from Memphis, a known source of endrin pollution to the Mississippi River. Thus the high values obtained during the three sampling periods could be an indication of a greater endrin contamination of the aquatic environment at the Tunica sampling station. However, this appears unlikely inasmuch as mean endrin concentrations in the blood of buffalo fish (Table 22) and catfish (Table 25) at the Tunica sampling station for all sampling periods were not appreciably different than at the other sampling stations. The high values could be due to chance or due to the movement of gizzard shad to the Mississippi River from the

Table 24. Mean concentration of endrin in blood of gizzard shad expressed in µg/g. The figure in parentheses represents the number of blood samples.

Sampling periods	Sampling station								All Stations
	Hickman	Memphis	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
2/19-23/65	-	-	-	-	-	-	.01 (1)	-	.01 (1)
3/25-26/65	-	-	-	-	.02 (2)	-	.05 (5)	-	.04 (7)
4/12-30/65	.09 (3)	-	-	.04 (5)	-	-	.10 (2)	-	.07(10)
5/6-28/65	-	-	-	-	.03 (1)	-	-	-	.03 (1)
6/11-18/65	-	-	-	-	.02 (1)	.48 (1)	-	-	.25 (2)
7/9-29/65	.11 (4)	-	-	-	-	-	-	-	.11 (4)
8/5-26/65	.01 (2)	-	-	.24 (2)	-	-	-	.03 (1)	.10 (5)
9/13-22/65	.02 (1)	-	-	-	.01 (1)	-	-	-	.02 (2)
10/11-30/65	-	-	.03 (1)	-	.03 (1)	.01 (4)	-	.01 (1)	.02 (7)
11/10-12/15,65	.00 (1)	-	.13 (2)	.03 (5)	.10 (2)	-	.03 (4)	.01 (1)	.05(15)
1/17-2/4,66	.01 (5)	-	.06 (3)	.02 (4)	.01 (5)	.01 (5)	.01 (5)	.00 (5)	.01(32)
2/25-3/19,66	.12 (3)	-	.26 (5)	.02 (5)	.02 (5)	.05 (3)	.01 (4)	.06 (3)	.08(28)
4/21-5/10,66	.02 (5)	-	.03 (5)	.00 (1)	.00 (5)	.00 (1)	.02 (5)	.02 (5)	.02(27)
6/6-24/66	.00 (5)	-	.00 (5)	.01 (5)	.01 (5)	.11 (6)	-	.01 (5)	.03(31)
7/11-29/66	.00 (5)	-	.00 (5)	.01 (5)	.00 (5)	.01 (1)	.00 (3)	.01 (5)	.00(29)
8/22-9/9,66	.00 (5)	-	.02 (5)	.01 (5)	.01 (5)	.00 (5)	.00 (5)	.00 (5)	.01(35)
11/15-12/10,66	.00 (2)	-	.65 (5)	.01 (5)	-	.01 (5)	-	-	.20(17)
All periods	.03(41)	-	.15(36)	.03(42)	.01(38)	.05(31)	.02(34)	.02(31)	.04(253)

Table 25. Mean concentration of endrin in blood of catfish expressed in µg/g. The figure in parentheses represents the number of blood samples.

Sampling periods	Sampling station								All stations
	Hickman	Memphis	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
2/19-23/65	.04 (1)	-	-	-	-	-	-	-	.04 (1)
3/25-26/65	-	-	-	-	.07 (1)	-	-	-	.07 (1)
4/12-30/65	.03 (5)	.02 (1)	-	-	-	-	-	-	.03 (6)
5/6-28/65	-	-	-	-	.03 (2)	-	-	-	.03 (2)
6/11-18/65	-	-	-	-	-	-	-	-	-
7/9-29/65	.03 (3)	.06(10)	-	.33 (3)	-	-	.03 (1)	.03 (5)	.06(22)
8/5-26/65	.02 (3)	.02 (5)	-	.02 (1)	.06 (1)	.01 (1)	.06 (4)	.03 (4)	.03(19)
9/13-22/65	.02 (4)	-	-	-	-	-	-	-	.03 (4)
10/11-30/65	.02 (2)	-	.02 (2)	-	.02 (3)	.01 (2)	.02 (3)	.01 (1)	.02(13)
11/10-12/15,65	.01 (1)	-	.05 (1)	.01 (4)	.05 (2)	-	.03 (3)	-	.03(11)
1/17-2/4,66	.01 (5)	-	.00 (2)	.01 (1)	.01 (4)	.02 (4)	.00 (2)	.01 (5)	.01(23)
2/25-3/19,66	.04 (4)	-	.11 (5)	.04 (5)	.04 (5)	.08 (1)	.05 (4)	.04 (3)	.06(27)
4/21-5/10,66	.05 (5)	-	.09 (5)	.10 (2)	.01 (3)	-	.02 (4)	.01 (2)	.05(21)
6/6-24/66	.00 (2)	-	.00 (5)	.06 (5)	.03 (4)	.15 (4)	-	.00 (5)	.04(25)
7/11-29/66	.00 (5)	-	.01 (5)	.00 (5)	.00 (5)	.02 (5)	.00 (7)	.02 (5)	.01(37)
8/22-9/9,66	.00 (6)	-	.01 (3)	.00 (4)	.02 (5)	.01 (4)	.00 (5)	.00 (5)	.01(32)
11/15-12/10,66	.00 (1)	-	.06 (5)	.04 (5)	-	.03 (5)	-	-	.04(16)
All periods	.02(47)	.04(16)	.04(33)	.04(35)	.02(35)	.04(26)	.02(33)	.02(35)	.03(260)

Memphis area tributary streams such as the Wolf, Hatchie and Loosahatchie Rivers and Nonconnah Creek, which have a higher degree of endrin contamination than the other Mississippi River tributary streams.

The mean concentration of endrin in the blood of 260 catfish collected at all sampling stations and during all sampling periods was .03 µg/g (Table 25). Only the mean value of .33 µg/g in the blood of catfish from the Vicksburg sampling station during July of 1965 exceeded the critical levels of acute intoxication from endrin found to range from 0.23 to 0.28 µg/g for channel catfish. However, this mean was based on the analyses of blood samples from only three fish. Concentrations of endrin in the blood of catfish were the highest during July 1965 and February through March 1966. No time trends in the concentration of endrin in the blood of catfish were apparent and there were no appreciable differences in concentration between the sampling stations.

Concentrations of endrin in the blood of all species of fish were very similar. Overall mean values differed only by a maximum of .02 µg/g (Tables 22, 24 and 25) ranging from a mean of .02 µg/g endrin for buffalo fish to a mean of .04 µg/g for gizzard shad.

Available data seemed to indicate that the mechanism of resistance to high endrin concentrations for resistant populations of a species of fish was physiological toleration of endrin accumulations see Chapter 3, Toxicity of Endrin. Available evidence, even though not extensive, seems to indicate that there were no differences in the uptake of endrin from the aquatic environment by resistant and nonresistant specimens of the same fish species. Going one step further, it is possible that uptake of endrin for different species of fish in the same aquatic environment was similar and that differences in critical levels of endrin in the blood indicative of acute intoxication were due to physiological toleration of different accumulations of endrin. If this was true then the pooling of the blood samples from the three species of fish should have given a better measure of endrin contamination of the aquatic environment. The similarity of the overall mean concentration for the three types of fish would also seem to be an indication that their rates of uptake of endrin were very similar. Pooling would increase the sample size and thus allow a more precise determination to be made, as well as allowing a better composite of endrin contamination in the various habitats occurring in the aquatic environment.

The mean concentration in the blood of 854 fish of all species collected at all sampling stations and during all sampling periods was .03 µg/g (Table 26). Concentrations of endrin in the blood were the highest during June and July of 1965 and December 1965 and January 1966. However, the high concentration of .10 µg/g during December 1965 and January 1966 for all stations was due to the high concentration of .28 µg/g encountered in the blood of fish from the Tunica sampling station. No time trends in the concentrations of endrin in the blood were apparent. The mean concentration for all sampling periods was somewhat higher at the Tunica sampling station than the other sampling stations. This was due mainly to high concentrations in the blood of gizzard shad obtained during 3 sampling periods.

Occurrence of Endrin in Saltwater Fish. The mean concentration of endrin in the blood of 71 saltwater fish of three species collected at Garden Island Bay sampling stations located just off the mouth of the Mississippi River (Figure 23) was .02 µg/g (Table 27). There were no appreciable differences in overall mean blood concentrations among the three species of fish. The mean concentration in the blood of largescale menhaden for all sampling periods was .02 µg/g while the mean concentration for sand seatrout and Atlantic croaker was .03 and .02 µg/g respectively. These concentrations are within the range found in the blood of the freshwater species of fish. Critical levels of endrin in the blood indicative of acute intoxication for the saltwater species of fish sampled were not determined; however, all mean concentrations were less than .10 µg/g with the exception of one mean of .10 µg/g based on blood samples from three largescale menhaden collected during October of 1965. No time trends in the concentrations of endrin in the blood of the saltwater fish were apparent. The data indicated that the same approximate degree of endrin contamination occurred in the saltwater aquatic environment just off the mouth of the Mississippi River as in the fresh water of the Mississippi River.

Discussion. Endrin was present in the aquatic environment in the Lower Mississippi and Atchafalaya Rivers during the period February 1965 through September 1967. However,

Table 26. Mean concentration of endrin in blood of all freshwater fish expressed in µg/g. The figure in parentheses represents the number of blood samples.

Sampling periods	Sampling station								All stations
	Hickman	Memphis	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
2/19-23/65	.04 (1)	-	-	-	-	-	.01 (1)	-	.03 (2)
3/25-26/65	-	-	-	-	.03 (3)	-	.05 (5)	-	.05 (8)
4/12-30/65	.04(22)	.02 (3)	-	.03 (9)	-	-	.06 (7)	-	.04(41)
5/6-28/65	-	-	-	-	.03 (6)	-	.05 (5)	-	.03(11)
6/11-18/65	-	-	-	-	.04 (6)	.16 (5)	-	-	.09(11)
7/9-29/65	.07 (8)	.06(10)	-	.18 (7)	.02 (1)	.03 (5)	.07 (8)	.03 (8)	.07(47)
8/5-26/65	.01(10)	.02 (6)	-	.10 (7)	.02 (6)	.00 (6)	.05 (8)	.03 (7)	.03(50)
9/13-22/65	.02 (6)	-	-	.03 (2)	.01 (3)	-	.00 (2)	-	.01(13)
10/11-30/65	.02 (2)	-	.03 (4)	-	.01 (9)	.01(11)	.02 (5)	.02 (4)	.02(35)
11/10-12/15,65	.01 (3)	-	.10 (3)	.02(14)	.04 (7)	-	.03(11)	.00 (3)	.03(41)
1/17-2/4,66	.01(15)	-	.02 (8)	.02(10)	.01(14)	.02(13)	.01(12)	.01(14)	.01(86)
2/25-3/19,66	.08(12)	-	.16(14)	.03(15)	.02(15)	.04 (9)	.03(13)	.04 (9)	.06(87)
4/21-5/10,66	.03(15)	-	.04(15)	.03 (8)	.00(13)	.02 (6)	.02(14)	.01(12)	.02(83)
6/6-24/66	.00(12)	-	.01(15)	.02(20)	.01(14)	.08(20)	-	.01(15)	.03(96)
7/11-29/66	.00(15)	-	.01(15)	.00(15)	.00(13)	.03(11)	.00(15)	.01(15)	.01(99)
8/22-9/9,66	.00(16)	-	.01(12)	.01(14)	.01(15)	.00(14)	.00(15)	.00(15)	.00(101)
11/15-12/10,66	.00 (4)	-	.28(13)	.02(15)	-	.02(11)	-	-	.10(43)
All periods	.02(141)	.04(19)	.07(99)	.03(136)	.02(125)	.04(111)	.03(121)	.01(102)	.03(854)

Table 27. Mean concentration of endrin in blood of fish collected from Garden Island Bay expressed in µg/g. The figure in parentheses represents the number of blood samples.

	Kind of fish			
Sampling periods	Largescale Menhaden	Seatrout	Atlantic Croaker	All fish
4/21/65	.02 (5)	-	-	.02 (5)
5/12-13/65	.03 (2)	-	-	.03 (2)
8/30-31/65	.00 (3)	-	-	.00 (3)
10/4-5/65	.01 (2)	-	-	.01 (2)
10/28-29/65	.10 (3)	-	-	.10 (3)
12/29-30/65	.00 (5)	-	-	.00 (5)
2/8/66	.03 (4)	-	.03 (3)	.03 (7)
3/30/66	.03 (3)	.02 (1)	.06 (2)	.04 (6)
5/17/66	.02 (5)	.08 (3)	.04 (3)	.04 (11)
6/28-29/66	-	.01 (4)	.03 (5)	.02 (9)
8/10-11/66	-	.00 (3)	.00 (5)	.00 (8)
1/11/67	.00 (5)	-	.01 (5)	.00 (10)
All periods	.02 (37)	.03 (11)	.02 (23)	.02 (71)

endrin levels during this period did not exceed concentrations which freshwater fishes can physiologically tolerate. This is also evident from the fact that no catastrophe, such as the 1963-64 fish kills has occurred to the fish populations since the fall of 1963 and early winter of 1964. Concentrations of endrin in the blood of fish are an excellent measure of endrin contamination of the aquatic environment, as fish are very efficient at concentrating and compositing endrin in the aquatic environment. However, because of the variability of such data, careful attention needs to be given to analyzing blood samples from a sufficient number of fish which will give a precise enough estimate to meet the objective of the sampling program. The Mississippi River is a source of endrin pollution to the marine and estuarine environments along the Louisiana coast, as evidenced by levels of endrin concentrations in the blood of saltwater fishes.

Occurrence of Endrin in Oysters

Concentrations of endrin in oysters (Ostrea virginica) collected from estuarine areas associated with the Mississippi River were determined for three sampling periods, January 7 through September 29, 1964; November 10, 1964 through June 23, 1965; and October 13 through June 15, 1965. Sampling stations for oysters (Figure 24) were selected which are considered as representing the most important oyster growing areas from the standpoint of yielding information concerning the level or possible buildup of endrin pollution. The oyster growing beds sampled included areas near lakes or siphons from which Mississippi River water is introduced onto oyster beds or areas that indirectly receive water drifting back from the passes at the mouth of the Mississippi River. Events necessitated some changes in the oyster beds sampled from period to period, e. g., Hurricane Betsy which struck the Lower Mississippi River region on September 9, 1965 devastated some of the oyster reefs routinely sampled.

Oyster samples were collected with a 12-tooth dredge operated manually and each sample consisted of approximately 40 oysters collected at a station. The initial step in analyzing for endrin content in the oysters consisted of blending shucked, drained oysters from each sample in a blender to obtain a homogenous mixture. All oysters were analyzed by the Gulf Coast Shellfish Sanitation Research Center Laboratory, U. S. Public Health Service.

During the three sampling periods, the percent of the samples found positive for endrin ranged from 3.1 to 30.8 percent (Table 28). Endrin concentrations above .01 µg/g in the oyster samples varied only within narrow limits, i. e., from .01 to .07 µg/g. Even though there was some contamination of the aquatic environment during the periods sampled, as indicated by endrin being found in the oyster samples, endrin concentrations were of very low levels. The range of endrin concentration in the oyster samples were generally of the same magnitude as those found by the U. S. Food and Drug Administration in 1964 in the analyses of 72 composite samples of twelve food groups comprising the American food supply. These amounts of endrin residues found by the Food and Drug Administration were reported as insignificant from a health standpoint (44).

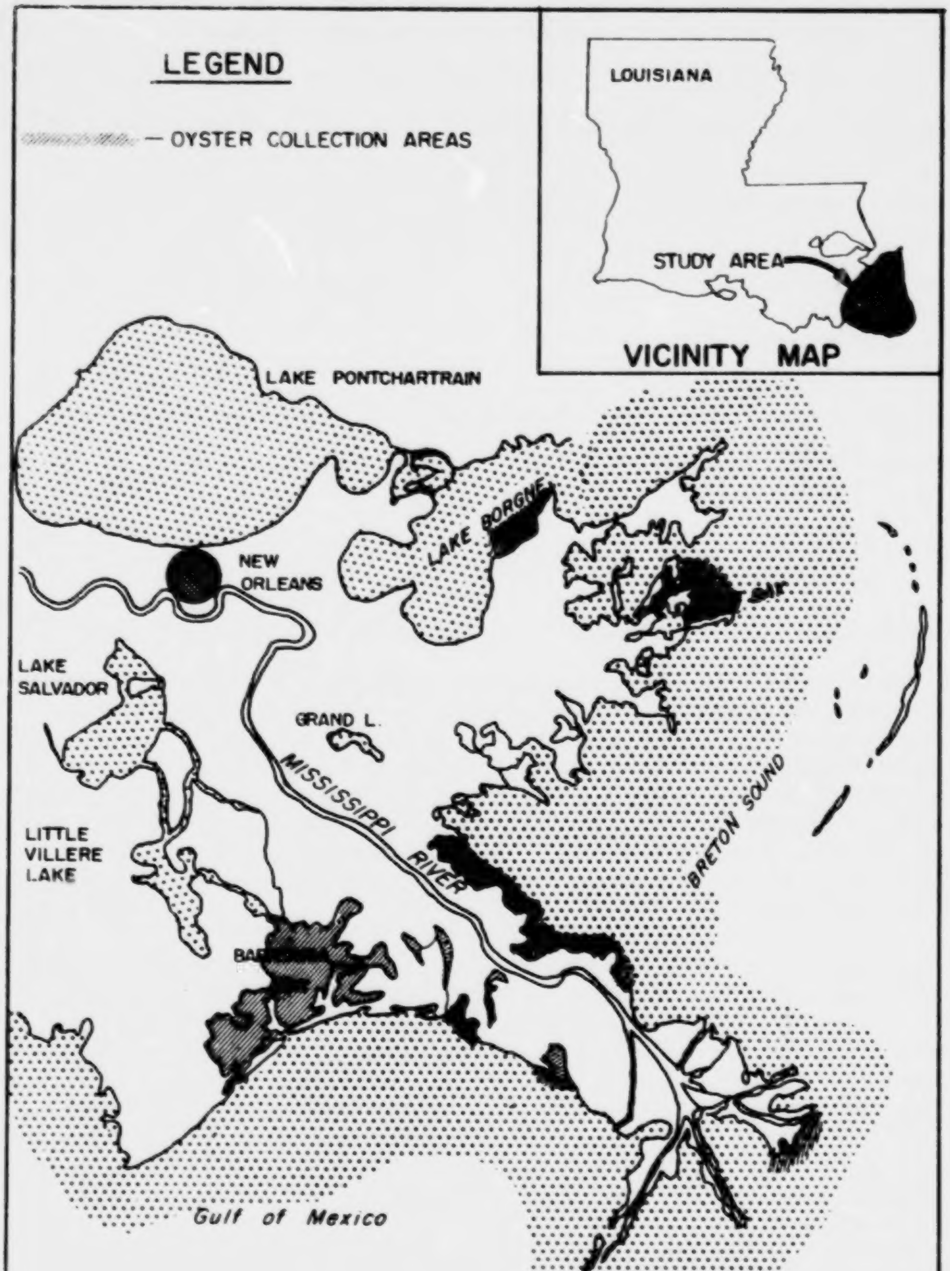
LEGEND
— OYSTER COLLECTION AREAS
LOUISIANA
STUDY AREA
VICINITY MAP
LAKE PONTCHARTRAIN
LAKE BORGNE
NEW ORLEANS
LAKE SALVADOR
GRAND L.
MISSISSIPPI RIVER
BRETON SOUND
LITTLE VILLERE LAKE
Gulf of Mexico

Figure 24 — Location of areas at which oysters were collected for determination of endrin content.

Table 28. Occurrence of endrin in oysters from estuarine areas associated with Mississippi River.

	Jan. 7 - Sept. 29, 1964	Nov. 10 - June 23, 1965	Oct. 13 - June 15, 1965
Number of samples	38	81	64
Number positive for endrin*	4	25	2
Percent positive for endrin*	10.5	30.8	3.1
Range of µg/g of endrin in positive samples	.01 - .01	.01 - .07	.01 - .01

* Only includes samples with at least .01 µg/g endrin.

Investigation of Fish Kills

In late 1964, state regulatory agencies responsible for water pollution control in Arkansas, Louisiana, Mississippi, and Tennessee as well as the U. S. Geological Survey and U. S. Army Corps of Engineers were asked to provide the Lower Mississippi River Technical Assistance Project with names and addresses of persons who frequently observed the Mississippi and Atchafalaya Rivers or their major tributaries and who would possibly be interested in participating in a fish kill reporting network.

Prospective participants were contacted in December 1964 by letter explaining the need and nature of the fish reporting network and giving instructions for reporting kills by telephone. Also, questionnaires and self-addressed envelopes were supplied to document an observed fish mortality. Network participants were periodically (twice during the first six months of 1965 and monthly since then) contacted by letter and furnished new questionnaires for reporting. New participants were added periodically to the network.

Tow boat operators of four tow boat companies radioed their headquarters to report fish deaths on the Mississippi and Atchafalaya Rivers. In turn, these companies advised the

Project by telephone of mortalities reported by their boat operators.

Personnel of state regulatory agencies responsible for water pollution control and the U. S. Geological Survey also participated in the network, but were not contacted periodically by letter. Also, telephone reports from individuals and State and Federal agencies, as well as information from other sources as the news media were useful in determining occurrence of fish kills. A total of 34 of 52 people contacted by letter agreed to participate in the fish kill network.

When a report of a fish kill was received, it was discussed with the state regulatory agency responsible for water pollution control in the state in which the kill was reported to have occurred. If the cause of the kill was unknown, a field investigation was made by the Project and/or the responsible state agency.

During field investigations involving fish mortalities, Project personnel measured dissolved oxygen, pH, conductivity and temperature of the water. These analyses were performed in order to aid in the determination of the causes of the kills. Dead or dying fish were collected and blood and/or liver and muscle tissue were obtained for analyses of endrin content. Also, samples of water and/or bed material were obtained for analyses of endrin content.

Fish kills investigated, and results of samples analyzed for endrin, revealed that in two kills, which occurred in May and October 1965 in the Wolf River at Memphis, Tennessee, endrin concentrations in blood samples from dead or dying gizzard shad exceeded by an order of magnitude the minimum level found to be indicative of acute intoxication from endrin. However, in both cases the dissolved oxygen measured was zero. The following summarizes these two fish kills as well as the other six kills investigated:

1. January 12, 1965, Baton Rouge Harbor, Mississippi River, Louisiana: Five hundred dead shad and gar were observed in upper end of harbor and 100 dead fish of various species were observed in a small bayou off the harbor. The D.O. ranged from 3.8 mg/l at the surface to 0.2 mg/l at the bottom.

2. May 19 and 20, 1965, Wolf River at Thomas Street Bridge, Memphis, Tennessee: Five hundred dying shad and gar fish were observed in a 400 by 400 foot area on May 19 and 1500 dying fish were observed on 350 yards of one bank on May 20. The D.O. was zero. Endrin concentrations in blood samples of 4 gizzard shad were 0.18, 0.32, 0.51 and 0.72 µg/g.

3. June 14 and 16, 1965, Loosahatchie River off Mississippi River, Memphis, Tennessee: 1500 dead fish, mostly shad, were observed on June 14. The D.O. was 0.5 mg/l and the pH 7.2. On June 16, 250 dead or dying shad were observed. Endrin concentrations in blood samples of five gizzard shad taken on June 16 were 0.01 and 0.01 µg/g.

4. July 7, 1965, Harvey and Algiers Canals, Intercoastal Waterway, New Orleans, Louisiana: 6,000 dead fish were observed of which 75 percent were channel catfish. The D.O. ranged from 0.8 to 1.2 mg/l. No samples were collected for endrin analysis.

5. October 1 and 2, 1965, Wolf River, Memphis, Tennessee: One million or more dead shad and dying carp were observed in a slough off Wolf River approximately two miles downriver from Wolf River Interceptor bypass sewer. The D.O. was zero. Endrin concentrations in blood samples of four gizzard shad in convulsions were 0.27, 0.40, 0.94 and 1.24 µg/g and of six carp in convulsions were 0.06, 0.31, 0.57, 0.92, 3.20 and 5.60 µg/g. Two water samples had endrin concentrations of 0.17 and 0.36 µg/l. Four bed material samples had endrin concentrations of 5.00, 5.00, 5.00 and 7.00 µg/kg.

6. January 13, 1966, Dennis Pass, Mississippi River to Gulf of Mexico: Investigation was made by the Louisiana Stream Control Commission. They reported several thousand dead fish (saltwater species only) observed in Dennis Pass. D.O. and pH were reported to be normal. Endrin concentrations in blood samples of 2 croaker were 0.04, and 0.04 µg/g and of 2 white trout were 0.09 and 0.42 µg/g.

7. February 4, 1966, McKellar Lake off Mississippi River, Memphis, Tennessee: Five to ten thousand dead and dying gar, shad, carp, buffalo, sauger, minnows and catfish were observed along north shore of lake. The D.O. was 8 mg/l and the pH varied from 7.1 to 7.5. Endrin concentrations in blood samples of two buffalo which were hemorrhaging were < 0.01 and 0.02 µg/g. Endrin concentration in four water samples were < 0.02, 0.04, 0.08 and 0.18 µg/l. Two bed material samples had endrin concentrations of 6.00 and 20.00 µg/kg.

8. May 20, 1966, Thomas Island Canal off Mississippi River, Memphis, Tennessee: Approximately 3,000 dead and dying fish were observed in one half mile of the canal downstream from the City of Memphis Thomas Island power generating plant. The D.O. was 5 mg/l, pH 7.2 specific conductance 300 and temperature 29°C. Endrin concentrations in blood samples of two carp in distress were 0.05 and 0.08 µg/g. Two water samples had endrin concentrations of 0.18 and 0.19 µg/l.

It is concluded that none of the eight fish kills investigated can be attributed to endrin alone and that no fish kills due to endrin pollution occurred on the main stem of the Mississippi and Atchafalaya Rivers during this Project.

Effects of Shallow Burial of Endrin on Surface and Ground Waters

In October 1964, the Velsicol Chemical Corporation began disposal of endrin wastes by shallow burial at a site in northeastern Hardeman County, Tennessee. Concerned with the possible effects of this practice on the quality of surface and ground waters in the area and the potentially adverse public health aspects, the U. S. Public Health Service requested the U. S. Geological Survey to investigate the disposal site and any measureable effects on the surface and/or ground waters of the area. In August 1967, a report of this study entitled, "Potential Contamination of the Hydrologic Environment from the Pesticide Waste Dump in Hardeman County, Tennessee" was submitted by the Geological Survey. A copy of this report is available for inspection in the office of Regional Director, South Central Region, Federal Water Pollution Control Administration, Dallas, Texas. The principal findings are quoted as follows:

"1. Is there now contamination of the environment from disposal pits; if so, what portion is now contaminated and to what degree?

The analytical results show clearly that the shallow burial of pesticide wastes in Hardeman County has contaminated portions of both the surface and subsurface environment at the disposal site. Evidence of contamination of the surface environment was found in samples of the surface soil at the disposal site, in samples of sediment washoff from the disposal site, and in samples of the bedload in Pugh Creek as far as 1 1/2 miles downstream from the site. On the other hand, the water portion of samples from Pugh Creek did not contain any detectable amounts of chlorinated hydrocarbons.

The degree of contamination of the surface environment is indicated by the following table which compares the analysis of plant waste with the maximum reported concentrations of pesticide materials in samples from various sampling sites.

Maximum value reported in analytical results

of soil and sediment samples

(Results in micrograms per kilogram)

Constituents	Plant Wastes	Sediment Washoff	Pugh Creek Bedload
Heptachlor	2.0 x 10	1600	3.2
Dieldrin	1.2 x 10	250	0.24
Endrin	4.5 x 10	73	0.10
Heptachlor epoxide	3.9 x 10	6.5	0.0

It is obvious from the foregoing table that attenuation accompanies the overland movement of the reported contaminants.

In the subsurface the buried wastes have produced a zone or enclave of contamination directly beneath and peripheral to the disposal pits. Laterally, the limits of the enclave appear to be confined within a distance of 25 feet from the outermost margins of the disposal pits. The depth of the enclave, however, extends nearly to the water table which is about 90 feet beneath the land surface.

Within the contaminated enclave the degree of contamination is greatest in the formation in which the wastes are deposited where values of up to 6 million µg/kg (micrograms per kilogram) of organic chlorine were found. It is least in the outermost fringe where a concentration of 5 µg/kg of organic chlorine was recognized as a positive indication of contamination. Attenuation of the contamination with depth was clearly evident in the analytical results.

II. What is the potential contamination hazard to local groundwater from percolation?

The vertical movement of the pesticide contaminants from the disposal pits poses a contamination hazard for 2 of the 3 groundwater bodies that occur beneath the disposal pits. The shallowest groundwater body (a perched water zone) has already become contaminated as evidenced by analytical results of water samples from shallow wells marginal to the disposal pits (see previous table). The portion of this zone, that is or can be contaminated, however, is limited in areal extent to about 40 acres. Moreover, it is not used as a source of water supply because it holds no water during dry seasons.

In addition to the perched water zone, a substantial portion of the local water table aquifer, the principal source of local domestic water supplies, is exposed to the hazard of contamination from the pesticide waste disposal pits.* The exposed portion has an areal extent of about 150 acres and includes the segments of the aquifer that underlie and receive recharge from the portion of the perched water zone that is susceptible to contamination, and the draws which carry contaminated washoff from the disposal site. In addition, it includes the part of the water table aquifer that is down gradient from the sources of potentially contaminated recharge.

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* There are no known wells in the 150 acre area, a fact not presented in the Geological Survey report quoted above. (Private communications from U.S.G.S.)

There is little likelihood that ground water in the artesian aquifer will ever be exposed to contamination from the disposal pits because this aquifer does not receive recharge from any of the aforementioned contaminated or potentially contaminated portions of the environment.

III. What is the potential contamination hazard to contiguous groundwaters?

The contaminants that are entrained in the flow systems of the perched water zone and the water table aquifer will move laterally toward the discharging boundaries of these groundwater bodies. The contaminants entrained in the perched water zone will move toward the discharging boundaries that are located within the surface ravines draining the disposal pits. The maximum rate of movement in the zone under prevailing hydraulic gradients is calculated to be about 2 feet per day. Hence, the entrained contaminants could reappear at the land surface in as little as 100 or as many as 1200 days after entry into the perched zone.

The contaminants entrained in the flow system of the water table aquifer will migrate northeasterly following the slope of the prevailing water table gradient. Eventually, these contaminants will be discharged into Pugh Creek. The minimum time that would be required for the entrained contaminants to reach the Creek is calculated to be 5 years.

Withdrawals from wells could conceivably induce the contaminants entrained in the flow system of the water table aquifer to move outside the portion of the aquifer that is in danger of contamination. Assuming the withdrawals are made at the maximum yield of the aquifer (40 gallons per minute) and continued for an indefinite period of time, wells on the western side of the disposal site (upgradient) would need to be located within 900 feet of the points of entry of contaminants into the aquifer in order for contaminated water to reach the point of withdrawal. Likewise, wells north or south of the disposal site (perpendicular to the prevailing gradient) would need to be located within 1500 feet of the potentially contaminated portion of the aquifer. If pumping is intermittent or at a lower rate than the maximum yield of the aquifer, the distance that potentially contaminated water can be diverted is, of course, commensurately less. Wells outside the limits indicated are in no potential danger of contamination by subsurface movement of contaminants.

IV. Are there other hydrologic factors related to contamination hazard that have become evident directly or indirectly from this study, such as topography, drainage, or runoff intensity?

The contaminants appear to have a greater affinity for clayey earth materials than for water. It is, therefore, doubtful that the contaminants will move as rapidly in the subsurface as ground water is able to move. It is also unlikely that contaminated particles of sediment in the draws and in Pugh Creek will be relieved of contaminants merely by association with water.

Certain features of the environment of the disposal site serve to delay the contamination hazard to the hydrologic system. These are:

1. The 90-foot depth to the water table
2. The presence of 3 beds of lowly permeable clayey material in the zone of aeration
3. The prevailing easterly water table gradient
4. The remoteness of the disposal site from local inhabitants.

Although not specifically questioned, it is pertinent that some of the pesticide waste is very acidic (pH 1-2). Some of the contaminated core samples were also acidic (pH 3.45). The presence of this acidic condition might increase or decrease the vertical permeability of the earth materials in the subsurface, and thereby affect the rate of vertical movement of contaminants through the zone of aeration."

CHAPTER 7

CONTROL OF ENDRIN POLLUTION

Much has been accomplished in the control of endrin pollution in the Lower Mississippi River Basin. That there has been no repetition of the endrin-caused fish kills in the Lower Mississippi and Atchafalaya Rivers such as occurred in 1963-64 testifies to this fact. A favorable commercial and sport fish population now exists in the Mississippi and Atchafalaya Rivers.

Endrin Manufacturing

Progress has been made in the control of endrin pollution from the Memphis, Tennessee area. In the fall of 1965, the Velsicol Chemical Corporation installed incinerating and vacuum filtering equipment in their manufacturing plant to reduce endrin and waste products leaving the plant. In September 1964, open dumping of waste containing endrin at the Hollywood Dump in Memphis was discontinued and Velsicol began burying residual waste on a farm in Hardeman County, Tennessee purchased for this purpose. Between October 8 and December 22, 1965, deposits of endrin-laden sludges in a 3,400 foot section of Wolf River interceptor sewer were removed by the City of Memphis and disposed of by burying at their endrin-laden sludges from Cypress Creek by burying at the Hollywood Dump and paving the surface of the burial area with asphalt.

Agriculture Use

The use of endrin in agriculture is decreasing, according to information provided by county agents in the Yazoo and Big Black River basins and the Shell Chemical Company. Hence, endrin pollution from agriculture has been and is being reduced and this trend is expected to continue.

Need for Surveillance

There is need for a program to maintain an effective aquatic environmental surveillance system in the Lower Mississippi River Basin. This system must include endrin and other pesticides and other materials having a measurable effect on the quality of the waters of the Basin.

Such a surveillance program would help prevent a reoccurrence of pollution conditions, such as those caused by endrin, which developed in the Lower Mississippi River Basin, culminating in 1963-64 fish kills.

Research on Removal of Endrin

From water. Research was undertaken to evaluate the effectiveness of water treatment processes in removing endrin. The major portion of the study used two 20 gpm (gallons per minute) water treatment pilot plants located at the Taft Sanitary Engineering Center, Cincinnati, Ohio. Endrin was added to Little Miami River (Ohio) water and its removal was determined following various treatment schemes. Complete details of this study are given by Robeck, et al. (45); therefore, only the pertinent conclusions follow: (1) Chlorine and potassium permanganate at 1-5 mg/l doses did not reduce endrin; (2) ozone required relatively large and impractical concentrations to reduce endrin approximately 50 percent; (3) about 10 mg/l of powdered activated-carbon slurry reduced 1 µg/l of endrin to 0.1 µg/l or 90 percent reduction; (4) fresh, granular activated-carbon beds were able to reduce 1 µg/l of endrin to or below 0.02 µg/l; and (5) the removal of endrin adsorbed on suspended particulates in water can be accomplished by coagulation and sedimentation; the removal will be proportional to the efficiency of the suspended solids removal; however, endrin in "solution" can only be effectively removed by activated carbon.

A water plant faced with an emergency situation of using raw water contaminated with endrin might: (1) Shut down until the situation corrected itself; (2) feed a slurry of an adsorbent e. g., powdered activated carbon; or (3) use granular carbon beds. The amount and type of adsorbent required, and thus the cost, would depend on the amount of endrin present, the amount of endrin to be removed, the availability of the adsorbent, presence of other organic material, and other factors. Adsorbents in slurry form would be used most effectively when the endrin concentrations were known; however, even when the endrin concentrations are unknown, large excesses of activated carbon could be used as a precaution without affecting the normal treatment process. For situations when endrin may be present at various concentrations during several times of the year, the continuous use of granular activated carbon beds appears to be the best solution at this time.

From Manufacturer's Waste. Routine visual observations in the laboratory of liquid Velsicol process wastes had indicated that much of the solid suspended material rapidly settled out in the sample containers. An experiment was designed to determine whether this settling process did in fact remove endrin from the bulk of the liquid.

On March 8, 1966 and again on March 21, 1966 four five-gallon grab samples were collected at the Velsicol plant, placed in glass carboys, sealed with teflon-lined lids, and shipped to the Baton Rouge laboratory for analyses.

The first of the two settling experiments was set up on March 15 using the March 8 samples and the second experiment was begun on March 29 using the March 21 samples. It was noted in the Baton Rouge laboratory that the physical appearance of the samples varied from one carboy to the next, e. g. some contained oil and other floating solids; other bottles contained a white suspended material; while others had a brown sediment. There was a pronounced chlorinated hydrocarbon odor in all bottles.

Both experiments were conducted in exactly the same manner. The five gallon carboys were used as the settling chambers. A propellar-type stirrer was inserted into each carboy, and the samples were stirred for two minutes at 170 rpm to insure complete mixing. Samples were drawn out with a glass siphon set one inch below the surface, and 800 ml of liquid were removed at time intervals of 0.0 (immediately after stirrer was stopped) 0.5, 2, 8, 24, 48 and 96 hours. Endrin was extracted and analyzed by the procedure for water described in Exhibit B.

Table 29 shows the results of the two experiments. It is apparent that a significant part of the endrin had settled below the siphon intake in both experiments at the end of 30 minutes. On the average, in Experiment 1, over 96% of the endrin had settled at the end of 30 minutes, and 60% in Experiment 2. Further settling time did not significantly reduce the endrin content in Experiment 1, and an apparent increase was noted during the final 48 hours of the experiment. Experiment 2 demonstrated that under the same conditions, a slower settling-out of the endrin was observed, but that at the end of 96 hours, 93% of the endrin had settled. This different rate of settling was probably due to normal variation in the physical makeup of the waste samples. These variations are further demonstrated in the ranges of endrin concentrations between the four replicants shown in Table 4.

These two experiments, although simple in design, suggest the use of settling tanks or ponds as a means of reducing the endrin content of liquid wastes.

Table 29. Experimental removal of endrin from manufacturer's liquid waste.

	Experiment 1			Experiment 2		
Settling time (hrs)	Endrin conc. (µg/l) Mean*	Range*	Percent Removal**	Endrin conc. (µg/l) Mean*	Range*	Percent Removal**
0	166.5	34.2-282.9	-	106.6	67.3-197.1	-
0.5	6.5	3.3-13.3	96	43.1	10.4-78.5	60
2	3.7	1.9-6.7	98	29.0	9.8-44.9	73
4	6.9	1.4-20.1	96	27.6	5.7-59.1	74
8	5.7	1.7-11.6	97	25.0	3.9-51.5	77
24	5.4	1.9-10.9	97	16.7	6.7-25.6	84
48	5.5	3.5-6.5	97	27.5	11.7-46.4	74
96	16.8	13.2-23.7	90	7.1	4.2-12.5	93

* Arithmetic average and range of four replicates.
** Based on mean endrin concentrations.

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EXHIBIT A

Members of the Interagency Coordinating Committee

Mr. K. S. Krause	Chairman - Representing the U. S. Public Health, Health Education and Welfare
Mr. Leo Iverson	Representing U. S. Department of Agriculture
Mr. J. W. Gentry	Representing U. S. Department of Agriculture
Mr. F. S. Snyder	Representing U. S. Corps of Engineers
Mr. W. H. Durum	Representing U. S. Geological Survey
Mr. John Buckley	Representing U. S. Science and Technical Commission

Members of the Technical Advisory Committee

Mr. J. E. Svore	Chairman - Representing U. S. Public Health Service, Health, Education & Welfare
Mr. Marvin Wood	Representing Arkansas State Pollution Control Commission through January 1967
Mr. S. Ladd Davies	Representing Arkansas State Pollution Control Commission after January 1967
Mr. J. E. Johnston	Representing Division of Sanitary Engineering Mississippi State Board of Health
Mr. S. Leary Jones	Representing Tennessee Stream Pollution Control Board
Mr. Robert Lafleur	Representing Louisiana Stream Control Commission
Mr. John Trygg	Representing Louisiana State Board of Health
Dr. Ernest Epps	Representing Louisiana Department of Agriculture

EXHIBIT B

ANALYTICAL PROCEDURES FOR ENDRIN

Introduction

Water, bed material and biological samples were analyzed for endrin by the following laboratories: 1. Lower Mississippi River Technical Assistance Project Laboratories (LMRTAP); 2. Pollution Surveillance Division Laboratory, Federal Water Pollution Control Administration, Cincinnati, Ohio; 3. Woodson-Tenent Laboratories (W-T), Memphis, Tennessee; 4. Research Division Laboratory, Federal Water Pollution Control Administration, Cincinnati, Ohio; and 5. Gulf Coast Shellfish Sanitation Research Center Laboratory (GCSSRC), Dauphin Island, Alabama.

Analytical procedures used by the participating laboratories differ to some extent because of the difference in the types of instruments, equipment and general laboratory facilities available and because of their different established routines. A general description of the analytical procedures used will be presented in this report; details of all techniques and equipment used will be included in a processed report or laboratory manual prepared by the Project or in the individual references given below.

Water

The same basic technique for extracting endrin from water was used by the LMRTAP, Pollution Surveillance, and W-T Laboratories listed above. The LMRTAP and W-T laboratories extracted approximately 0.80 liters of water for 1 hour with 35-50 ml of hexane while stirring with a magnetic stirring device as described by the Basic Data Branch of the U. S. Public Health Service, now Pollution Control Surveillance Division, Federal Water Pollution Control Administration (46). Pollution Surveillance used a hexane-benzene mixture (9:1) and extracted for 30 minutes. The liquid phases were then separated in a separatory funnel or by siphoning. The solvent(s) was dried with sodium sulfate and evaporated to a small volume. An appropriate aliquot of the solvents solution was then subjected to a silica gel-carbon tetrachloride thin layer chromatographic technique (47) in which the endrin and dieldrin were separated from all of the other pesticides.

The GCSSRC Laboratory used a liquid-liquid extraction with an ethyl ether-petroleum ether solvent mixture to remove the pesticides from the water. The entire extraction was done with separatory funnels involving three solvent changes. A florisil column using 6 percent ethyl ether in petroleum ether for elution was used for clean up, and 15 percent mixture was used to elute the endrin and dieldrin.

Gas chromatographs were used by all participating laboratories for the final separation and quantitation of endrin. The LMRTAP laboratory used a Micro-Tek Model GS 2000 R Gas Chromatograph* with dual columns and tritium source dual detectors. In addition, a Perkin-Elmer Model 820 Gas Chromatograph equipped with a Dohrmann Microcoulometric Automatic Recording Titration System was used for verification of many of the samples (48). The Basic Data Laboratory was equipped with an electron capture, Perkin-Elmer 154-L Gas Chromatograph, and a Perkin-Elmer 800 with a Dohrmann Microcoulometer.

The Woodson-Tenent Laboratories used a Micro-Tek 179 DSS and the GCSSRC Laboratory a Micro-Tek 2000 MF equipped with an electron capture detector coupled with a Dohrmann C-200 Microcoulometer.

Bed Materials

The methods for extracting endrin from bed materials or bottom sediments varied considerably between laboratories.

The LMRTAP Laboratory first split the wet sample with a riffle splitter until an appropriate sample was obtained (approximately 100 g). Selected samples were further split into sand, silt-clay and clay fractions by a combination sieving-decantation process (49). The whole sample or individual fractions contained in beakers were then extracted several times with acetonitrile and filtered. The acetonitrile filtrate containing the pesticides was transferred to a quart jar containing a saturated sodium sulfate solution and a 15 percent ethyl ether in petroleum ether solvent mixture. This mixture was stirred with a magnetic stirrer, separated and then reextracted with fresh solvent. The combined extracts were passed through a variegated column of sodium sulfate-aluminum oxide for the removal of water and most oils. This eluate was then reduced to apparent dryness and taken up in a small quantity of hexane. The thin layer cleanup and separation and subsequent quantitation by gas chromatography were the same as for the water samples.

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* Mention of products and manufacturers is for identification only and does not imply endorsement by the Federal Water Pollution Control Administration or the U. S. Department of the Interior.

The Pollution Surveillance Division Laboratory first air-dried the bed material samples and ground them with a mortar and pestle. The pesticides were extracted from the prepared sample in a Soxhlet extractor with a 9:1 hexane-acetone mixture. This extract was separated into aliphatic, aromatic, and oxygenated compounds on a column made up of silica gel; isooctane, benezene, and methanol-chloroform 1:1 respectively were used to elute these fractions from the column. The aromatic fraction containing the endrin was subjected to thin layer chromatography and the endrin quantitated by gas chromatography.

The Woodson-Tenent Laboratory also began their extraction with a finely ground, air-dried sample. The pesticides were extracted with acetonitrile using an Omnimixer for clays and by shaking in a jar for sand or gravel. The acetonitrile extract was then partitioned with petroleum ether, water, and a saturated sodium sulfate solution in a separatory funnel. The petroleum ether extract was dried with sodium sulfate and transferred to a florisil column which was eluted with petroleum ether-ethyl ether. This eluate was evaporated to a small volume and transferred to a partially deactivated alumina column which was eluted with petroleum ether for the second cleanup procedure. An aliquot of the eluate from this column was injected into the gas chromatograph for the final quantitation of the endrin.

The Gulf Coast Shellfish Laboratory used a direct extraction of endrin from the wet bed material. One Hundred grams of sample were blended with 175 ml of a 10-90 acetone-acetonitrile mixture. The slurry was centrifuged, and the supernatant transferred to a separatory funnel containing 1000 ml of an aqueous solution of sodium sulfate and 125 ml of petroleum ether. After extraction the petroleum ether layer was recovered and rewashed with aqueous sodium sulfate which was then discarded. The petroleum ether fraction was then air evaporated to a small volume and transferred to an activated florisil column which was eluted with an ethyl ether-petroleum ether mixture. The eluate was reduced in volume and a suitable aliquot was injected into a gas chromatograph for measurement of the endrin.

Biological Materials

Whole oysters and samples of fish blood, muscle, and liver were analyzed for endrin. Fish were analyzed by the Research Division and the Woodson-Tenant Laboratories while oysters were analyzed by the Gulf Coast Shellfish Sanitation Research Center Laboratory.

Woodson-Tenent Laboratory's method for endrin analysis of fish tissues was similar to their bed material extraction technique. One to two gram samples were blended with acetonitrile in an Omnimixer and the filtered extract was partitioned between ether and an aqueous sodium sulfate solution. The petroleum ether containing the pesticides was first passed through a florisil column and then through an alumina column for final cleanup. An aliquot of the eluate from the alumina column was analyzed for endrin with the gas chromatograph.

The Research Division Laboratory subjected the tissue samples to a rapid saponification with an ethanolic potassium hydroxide solution and heat. After saponification, the degraded tissues were extracted with hexane in a separatory funnel and the hexane layer was removed. An aliquot of the hexane extract was reduced to dryness with air and the residue was redissolved in a 20 percent ethyl ether in hexane mixture and spotted on a silica gel thin layer plate. After development with carbon tetrachloride, endrin containing portions of the plate were removed and endrin was measured on the electron capture or microcoulometric gas chromatograph.

The initial step in the method for extracting endrin from oysters consisted of blending shucked, drained oysters in a blender to obtain a homogeneous sample (50). Five grams of this material was extracted with acetonitrile in a blender. The homogenate was transferred to a basket centrifuge and the centrifugate, together with a second extract of the oyster tissues, was collected in a separtory funnel containing 1000 ml of an aqueous sodium sulfate solution and 100 ml of petroleum ether and shaken for five minutes. After separation, the aqueous layer was discarded and the petroleum ether was dried with anhydrous sodium sulfate and evaporated to approximately 25 ml. The petroleum ether extract was then passed through a sodium sulfate-florisil column for cleanup and separation (51), and the endrin in the eluate was measured by gas chromatography.

Lower Limits for Reporting Endrin

Because of differences in techniques, instrumentation, and the type and size of samples, different lower limits for endrin were reported by the cooperating laboratories. Except for the GCSSRC Laboratory, whose results were presented as received, all endrin concentrations were adjusted to reflect the following lower limits: 1. endrin in water, 0.02 μg/l; 2. endrin in bed materials, 0.16 μg/kg; and 3. endrin in fish tissues (blood, muscle, and liver), 10 μg/kg. Any values below these limits were reported as "less than" these lower limits and were considered "zero" in all calculations.

It should be noted that these lower limits did not imply that endrin could not be measured in lesser amounts, but considering sample size and chromatographic techniques used, these limits were judged to be the most reliable minimal quantities that could be reported.

Comparison of Laboratories

A series of interlaboratory studies was conducted to compare results from endrin-spiked water samples. In one study Mississippi River water from Hickman, Kentucky was allowed to settle in order to remove the settleable solids and then decanted. The supernatant was then extracted three times with hexane to remove the extractable organic materials. This extract was subdivided and each portion was spiked with known amounts of endrin dissolved in acetonitrile. Two samples of each concentration of endrin spiked portions were then analyzed by each participating laboratory. The mean percent recovery is shown in Table B-1 below. An analysis of variance was performed on these data utilizing a two factor

Table B-1 Percent recovery of spiked water samples by laboratories.

Nanograms of endrin added	Laboratory				
	LMRTAP	Basic Data	Woodson-Tenent	GCSSRC	Total
6	158.4*	200.0	191.7	50.0	150.0
48	117.7	71.9	147.9	217.8	138.8
240	51.7	45.8	96.1	139.4	83.2
480	63.4	50.9	93.2	136.3	85.9
Total	97.8	92.1	132.1	135.9	114.5

* All values are the mean of two samples.

model, where deviations due to different laboratories were considered a fixed factor and deviations due to different endrin concentrations were considered a random factor. Differences in percent endrin recovered from samples spiked with different concentrations of endrin were found to be significant (F=10.74, with 3 and 16 degrees of freedom; $P < .01$); also, a significant interaction between laboratories performing the analyses and samples spiked with different concentrations of endrin was found (F=7.21, with 9 and 16 degrees of freedom; $P < .01$). Thus, it appears that the accuracy of endrin concentrations determined by different laboratories will vary with the concentrations being measured.

In another experiment, Mississippi River water from north of Baton Rouge was allowed to settle to remove the settleable solids, decanted and the supernatant was extracted three times with hexane to remove the extractable organic materials. This extracted water was then subdivided and 4 portions were spiked with 2500 nanograms of endrin dissolved in acetonitrile. The spiked portions were then analyzed by each participating laboratory. The LMRTAP, Basic Data, Woodson-Tenent, and GCSSRC Laboratories recovered a mean percent of 49.4, 45.2, 111.4, and 97.8 of endrin, respectively. An analysis of variance was performed on these data utilizing a one factor fixed model. Percent recoveries differed significantly between laboratories (F= 72.117 with 3 and 12 degrees of freedom; $P< .01$); however, such high concentrations are not normally encountered in the field, except in the Memphis area.

In additional tests, two sets (one standard each) of standard endrin solutions were prepared by LMRTAP Laboratory - one set containing 200 ng endrin in 5 ml hexane was distributed. Recoveries of 101.5, 96.0, 99.5, and 86.5 percent were reported by LMRTAP, Basic Data, Woodson-Tenent, and GCSSRC Laboratories, respectively. The other set containing 2500 ng endrin in 5 ml hexane was distributed and recoveries of 61.4, 93.0, 100.0 and 88.8 percent were reported by LMRTAP, Basic Data, Woodson-Tenent and GCSSRC, respectively.

It is concluded that there are some differences in the results of split water samples analyzed for endrin by different laboratories. Depending upon the use and accuracy desired, caution should be exercised in using data from different laboratories interchangeably.

EXHIBIT C

BIODEGRADIBILITY OF ENDRIN

Studies of the biodegradibility of endrin were performed in a laboratory apparatus designed to simulate the thermal and dissolved oxygen profiles found in a typical stratified reservoir (See Figure C-1). The apparatus consists of an aluminum tank 3 feet in diameter and approximately 11 feet tall, which holds 500 gallons of test media. The upper two thirds of the water column is maintained at approximately 23°C. by a thermostatically controlled 12-KW immersion heater. The bottom third of the water column is maintained at about 12°C. by a thermostatically controlled refrigerator. Upper water is circulated by the continuous operation of a small mixer. Samples may be withdrawn from the upper and lower water through sample ports, and an injection port is available for the introduction of materials into the bottom-water zone (See Figure C-1).

This apparatus was tested in several ways to demonstrate that its behavior was similar to that of stratified impoundment in the field. Temperature and dissolved oxygen concentration profiles showed the upper six feet of the water column to be warm and nearly saturated with dissolved oxygen, while the lower three feet were cold and the dissolved oxygen concentration was at, or near, zero. A transition zone of about one foot existed between the upper and lower waters. Nitrate tracer introduced at the surface of the water column was distributed throughout the warm zone in about 1/2 hour but penetrated the transition zone very slowly. Tracer introduced into the bottom zone passed into the upper waters very slowly, probably by molecular diffusion. On a shortened vertical scale, the water column was behaving physically in a manner similar to the field.

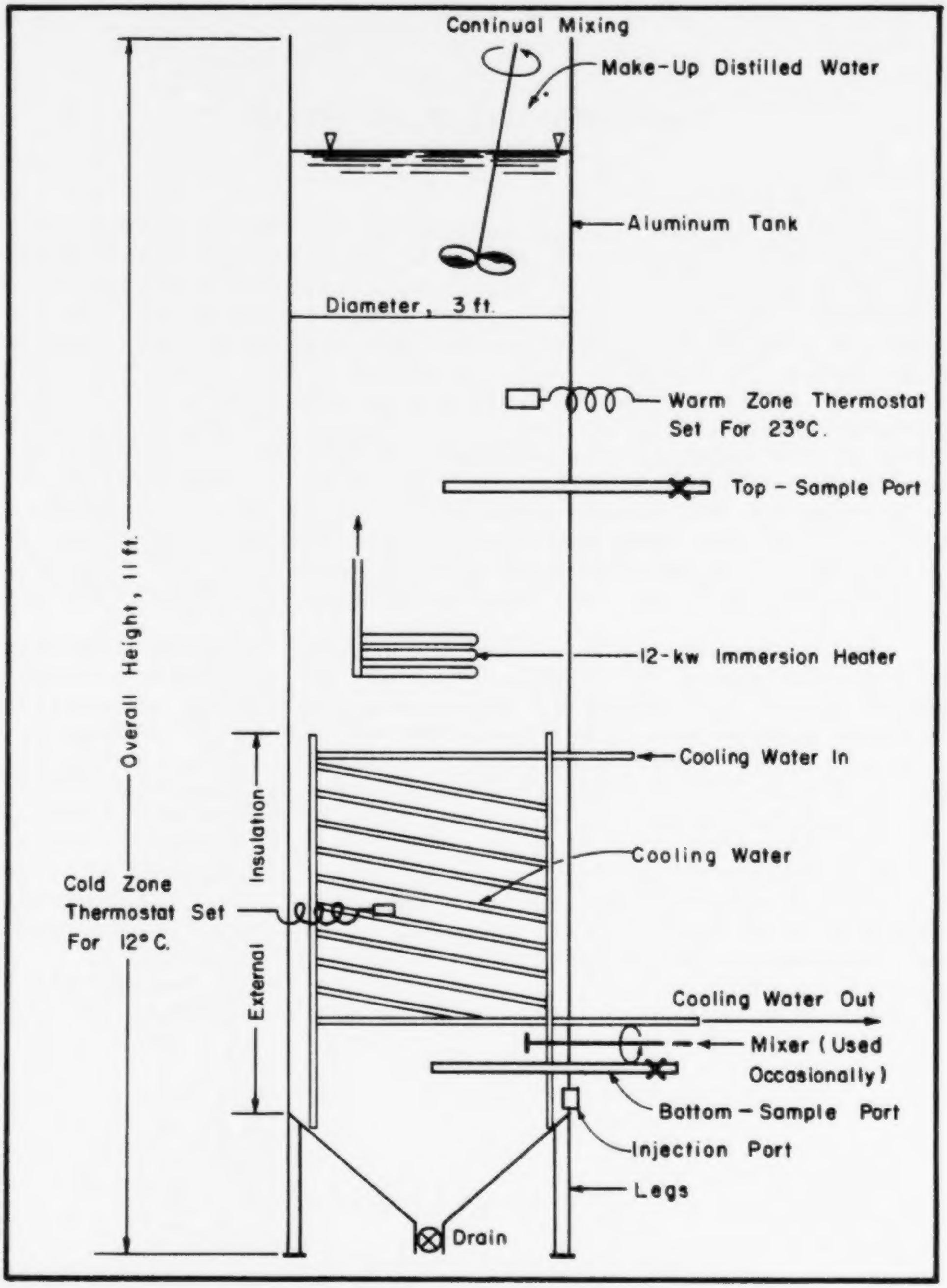
Continual Mixing
Make-Up Distilled Water
Aluminum Tank
Diameter, 3 ft.
Warm Zone Thermostat Set For 23°C.
Top - Sample Port
Overall Height, 11 ft.
12-kw Immersion Heater
Cooling Water In
Insulation
Cooling Water
Cold Zone Thermostat Set For 12°C.
External
Cooling Water Out
Mixer (Used Occasionally)
Bottom - Sample Port
Injection Port
Legs
Drain

Figure C-1 - Simulated stratified impoundment.

EXHIBIT D

RELATIONSHIP OF ENDRIN TO NONFILTRABLE RESIDUE IN RIVER WATER

Sampling equipment used by the Project to collect river water samples were of a type which would collect an unbiased sample of the suspended sediments present. The sampling design used resulted in the collection of samples from eight verticals located at the centroids of equal segments of discharge in the cross section of the stream at sampling stations located on the mainstem of the Mississippi River. Five sampling verticals were used on the Yazoo River. Individual samples were collected at 90, 70, 50, 30 and 10 percent of the total depth. At the Memphis, Vicksburg and Tarbert Landing stations, 40 samples collected November 18, November 21, and December 2, 1965, respectively, and at the sampling station on the Yazoo River, 25 samples collected November 16, 1965 were used for the analyses.

By modifying the normal endrin extraction technique described in Chapter 3, Analytical Procedures for Endrin, both the endrin content and the weight of the nonfiltrable residue were determined for the same sample. The sample was first filtered through Number 0, tared filter paper, and then both the nonfilterable residue and the filtrate were extracted with appropriate solvents to remove the endrin. The solvent extracts were combined and the total endrin content was quantitated in the usual manner. The filter paper with its contents was dried at 100°C. until constant weight was obtained, cooled in a desiccator and then weighed. The increase in weight over that of the empty filter was reported as the nonfilterable residue in mg/l.

In order to determine the relationship between endrin concentration and weight of nonfilterable residue in river water, the product-moment correlation coefficient, r, and the coefficient of determination, r^2, were calculated (See Table D-1).

To test the hypothesis that the difference between the observed values of r and o could be accounted for by chance, t-tests were conducted. At the .05 probability level only the correlation at the Tarbert Landing Station was significant (Table 3). Even though significant, less than ten percent of the variation in the concentration of endrin in the water samples could be attributed to changes in the weight of nonfiltrable residue (r^2 = 9.61 percent). This study would suggest that endrin concentrations have little relationship to the amount of suspended sediments of a size to be present in the nonfiltrable residue in river water. Considering the solubility of endrin in water (260 μg/l) and the range of endrin concentration encountered in the rivers sampled (0-112.17 μg/l) it is possible for the concentration of endrin to be unrelated to other particulate matter in river water.

Table D-1: Correlation of endrin concentrations to weight of nonfiltrable residue in river water.

Sampling station and date	r	r^2 (percent)	t	p	df
Memphis Nov. 18, 1965	.23	5.29	1.496	> 0.1	38
Vicksburg Nov. 21, 1965	-.03	0.09	0.154	> 0.1	38
Tarbert Landing Dec. 2, 1965	.31	9.61	2.114	< 0.05	38
Yazoo Nov. 16, 1965	-.16	2.56	0.787	> 0.4	23

EXHIBIT E

Table E-1 Toxicity of endrin to various species of fish as reported in the literature.

Authority	Type of measurement	Type of bioassay (endrin in µg/l) Flow-through	Static	Common and scientific names of test fish
Hebert et al.(52)	24 hr TL_m*	4.2	15.9	Mosquitofish, *Gambusia affinis*
	48 hr TL_m	2.5	14.5	Mosquitofish
Henderson et al.(13)	24 hr TL_m in soft water	-	1.8	Fathead minnow, *Pimephales promelas*
	24 hr TL_m in hard water	-	1.6	Fathead minnow
	48 hr TL_m in soft water	-	1.3	Fathead minnow
	48 hr TL_m in hard water	-	1.5	Fathead minnow
	96 hr TL_m in soft water	-	1.1	Fathead minnow
	96 hr TL_m in hard water	-	1.4	Fathead minnow
	24 hr TL_m in soft water	-	0.75	Bluegill, *Lepomis macrochirus*
	48 hr TL_m in soft water	-	0.75	Bluegill
	96 hr TL_m in soft water	-	0.66	Bluegill
	24 hr TL_m in soft water	-	5.6	Goldfish, *Carassius auratus*
	48 hr TL_m in soft water	-	2.3	Goldfish
	96 hr TL_m in soft water	-	2.1	Goldfish
	24 hr TL_m in soft water	-	3.4	Guppy, *Lebistes reticulatus*
	48 hr TL_m in soft water	-	2.8	Guppy
	96 hr TL_m in soft water	-	1.6	Guppy
Lowe (53)	24 hr LC_{50}**	2.6	-	Striped mullet, *Mugil cephalus*
	24 hr LC_{50}	0.45	-	Spot, *Leiostomus xanthurus*
	24 hr LC_{50}	0.80	-	Menhaden, *Brevoortia patronus*
	24 hr LC_{50}	0.32	-	Sheepshead minnow, *Cyprinodon variegatus*
	24 hr LC_{50}	0.23	-	Longnose killfish, *Fundulus similis*
	100 percent mortality 5 days of exposure	.10	-	Spot, *Leiostomus xanthurus*
	57 percent mortality 19 days of exposure	.075	-	Spot

* Median tolerance limit.

** Median lethal concentration.

Table E-1 Continued. Toxicity of endrin to various species of fish as reported in the literature.

Mount (54)	96 hr TL_m*	.27	-	29.8 mm bluntnose minnow, *Pimephales notatus*
	96 hr TL_m	.29	-	40.6 mm bluntnose minnow
	96 hr TL_m	.47	-	59.8 mm bluntnose minnow
Eisler (55)	96 hr TL_m	3.1	-	Northern puffer, *Sphaeroides maculatus*
Ferguson et al. (15)#	36 hr TL_m	-	3.0	State College, golden shiner, *Notemigonus crysoleucas*
	36 hr TL_m	-	310	Twin Bayou, golden shiner
	36 hr TL_m	-	1.5	State College, bluegill, *Lepomis macrochirus*
	36 hr TL_m	-	300	Twin Bayou, bluegill
	36 hr TL_m	-	3.4	State College, green sunfish, *Lepomis cyanellus*
	36 hr TL_m	-	160	Twin Bayou, green sunfish
Ferguson & Bingham(16)#	36 hr TL_m	-	1.25	Yalobusha, yellow bullhead, *Ictalurus natalis*
	36 hr TL_m	-	75.0	Belzoni, yellow bullhead
Ferguson et al. (17)#	36 hr TL_m	-	1.0	State College, mosquitofish, *Gambusia affinis*
	36 hr TL_m	-	2.0	Walls, mosquitofish
	36 hr TL_m	-	1.0	Greenville, mosquitofish
	36 hr TL_m	-	<0.5	Rodney Lake, mosquitofish
	36 hr TL_m	-	0.75	St. Francisville, mosquitofish
	36 hr TL_m	-	5.0	Yazoo City, mosquitofish
	36 hr TL_m	-	120	Sidon, mosquitofish
	36 hr TL_m	-	0.37	Norabee, black bullhead, *Ictalurus melas*
	36 hr TL_m	-	0.88	Greenville, black bullhead
	36 hr TL_m	-	2.5	Waysule, black bullhead
	36 hr TL_m	-	2.0	Ferridy, black bullhead
Ferguson et al. (14)#	36 hr TL_m	-	1	State College, mosquitofish, *Gambusia affinis*
	36 hr TL_m	-	1000	Belzoni, mosquitofish

* Median tolerance limit.

** Median lethal concentration.

# These TL_m values are for resistant strains of fish

Table E-1Continued. Toxicity of endrin to various species of fish as reported in the literature.

Authority	Type of measurement	Type of bioassay (endrin in µg/l) Flow-through	Static	Common and scientific names of test fish
Katz (56)	24 hr TL_m*	-	2.0	Chinook salmon, *Oncorhynchus tshawytscha*
	48 hr TL_m	-	1.2	Chinook salmon
	72 hr TL_m	-	1.2	Chinook salmon
	96 hr TL_m	-	1.2	Chinook salmon
	24 hr TL_m	-	1.3	Coho salmon, *Oncorhynchus kisutch*
	48 hr TL_m	-	0.8	Coho salmon
	72 hr TL_m	-	0.52	Coho salmon
	96 hr TL_m	-	0.51	Coho salmon
	24 hr TL_m	-	0.79	Rainbow trout, *Salmo gairdneri*
	48 hr TL_m	-	0.58	Rainbow trout
	72 hr TL_m	-	0.58	Rainbow trout
	96 hr TL_m	-	0.58	Rainbow trout
	48 hr TL_m(water 5 g/l salinity)		0.45	Threespine stickleback, *Gasterosteus aculeatus*
	72 hr TL_m(water 5 g/l salinity)		0.45	Threespine stickleback
	96 hr TL_m(water 5 g/l salinity)		0.44	Threespine stickleback
	72 hr TL_m(water 25 g/l salinity)		0.58	Threespine stickleback
	96 hr TL_m(water 25 g/l salinity)		0.50	Threespine stickleback
Katz & Chadwick (23)	24 hr TL_m	-	2.17	Rainbow trout, *Salmo gairdneri*
	48 hr TL_m	-	1.45	Rainbow trout
	72 hr TL_m	-	1.12	Rainbow trout
	96 hr TL_m	-	0.90	Rainbow trout
	24 hr TL_m	-	12.0	Coho salmon, *Oncorhynchus kisutch*
	48 hr TL_m	-	0.56	Coho salmon
	72 hr TL_m	-	0.30	Coho salmon
	96 hr TL_m	-	0.27	Coho salmon
	48 hr TL_m	-	1.50	Chinook salmon, *Oncorhynchus tshawytscha*
	72 hr TL_m	-	1.01	Chinook salmon
	96 hr TL_m	-	0.92	Chinook salmon

* Median tolerance limit.

** Median lethal concentration.

Table E-1Continued. Toxicity of endrin to various species of fish as reported in the literature.

	72 hr TL_m*	-	1.10	Guppy, *Lebistes reticulatus*
	96 hr TL_m	-	0.90	Guppy
	72 hr TL_m	-	0.95	Bluegill, *Lepomis macrochirus*
	96 hr TL_m	-	0.60	Bluegill
	48 hr TL_m	-	1.80	Mosquitofish, *Gambusia affinis*
	72 hr TL_m	-	1.05	Mosquitofish
	96 hr TL_m	-	0.75	Mosquitofish
	48 hr TL_m	(varying salinities)	1.74 - 2.62	Threespine stickleback, *Gasterosteus aculeatus*
	72 hr TL_m	(varying salinities)	1.57 - 1.95	Threespine stickleback
	96 hr TL_m	(varying salinities)	1.20 - 1.65	Threespine stickleback
Cottam (57)	96 hr TL_m	-	0.6	Bluegill, *Lepomis macrochirus*
	48 hr TL_m (28°C)	-	5.0	Carp fingerling, *Cyprinus carpio*
	48 hr TL_m (18°C)	-	6.0	Carp fingerling
	48 hr TL_m (8°C)	-	140.0	Carp fingerling

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* Median tolerance limit.

** Median lethal concentration.

EXHIBIT F

ENDRIN CONCENTRATIONS IN BLOOD OF FISH

During the 1963-64 investigations of large fish kills on the Lower Mississippi River, a direct relationship in channel catfish (Ictalurus punctatus) was observed between endrin concentration in blood and mortality (58).

The pesticide concentrations in various organs of animals have been measured frequently, but the purpose was often for survey data and not for toxicological studies. Among those who have tried to relate tissue concentrations with intoxication, Brown et al.(59) reported that in the blood of man and dogs there is a critical concentration of dieldrin above which clinical signs of intoxication appear. Burdick et al.(60) reported a relatively close relationship between the DDT content of eggs and fry mortality in lake trout (Salvelinus namaycush).

Dale et al.(61) found a relationship between the degree of illness and the concentration of DDT in the brain of rats, and they also noted a sharp rise in the plasma concentration of DDT after administration of the insecticide. The plasma concentration, however, remained nearly constant from the slight tremor stage through convulsions and death. In the Project studies to detect acute endrin toxicity, the concentration of endrin present in the blood of fish that have been exposed to endrin dispersed in water was used. It was reasoned that blood was the vehicle by which endrin reached the brain and that the concentration of endrin in the blood should be related to intoxication.

The measurement of pesticides in fat and brain has been traditional, probably because they occur in these tissues in greater concentrations and, therefore, are more easily measured. Endrin is a central nervous system poison; however, it is doubtful that the brain concentration of endrin in catfish would be indicative of acute intoxication because of the fat storage depots that exist in the brain of these fish. Although time has been insufficient to complete brain analyses, it seems probable that the amount stored would mask the amount needed to produce mortality. For this reason, and since the liquid portion of the blood bathes the brain and spinal cord constantly, blood seemed to be a better choice for diagnosing the cause of mortality. The relationship between endrin concentrations and acute active toxicity was determined for channel catfish and gizzard shad (Dorosoma cepedianum).

Endrin Concentrations in Blood of Channel Catfish

Channel catfish weighing from 200 to 500 grams were exposed to 15 different lethal and sublethal concentrations of endrin in water. The test water was renewed continuously by a serial dilution apparatus (62) from a water supply system similar to the one described by Lemke and Mount (63). Renewal of the endrin was necessary to maintain known and constant concentrations. Tap water was passed through a 17.5 cubic foot activated carbon filter as a safety precaution to remove traces of pesticides and then to a 100,000 gallon pond reservoir where it was detained 60 to 90 days before use. This detention period minimized daily variations in chemical characteristics. Tests were made at 15° and 22°C. ±1°C. in stainless steel troughs 1 by 1 by 6 feet. All water lines and valves were made of plastic or stainless steel; after the introduction of endrin, contact of the test water with plastic was minimized because many plastics readily adsorb endrin. The water flow rates were controlled between 200 and 400 ml/min, depending on the number of fish in the tank.

Fish were obtained from four locations (one in Arkansas and three in Ohio), and before exposure, all of them contained less than .03 µg/g endrin in the blood. Blood was obtained by drying and severing the caudal peduncle and allowing the blood to drip into an acetone-rinsed vial; the sample was then kept frozen until analysis.

Figure F-1 depicts the relationship of the amount of endrin in the blood to the exposure time and lethality. In approximately 90 percent of the 95 exposed fish that were analyzed, the concentration of endrin in the blood of fish killed by endrin poisoning was greater than the concentration of endrin in the blood of fish that were exposed to endrin in the water but not killed. In nonlethal exposurers to endrin, lasting as long as 44 days, the concentration of endrin in the blood was not as high as it was in fish killed by endrin. For example, four fish were exposed to 0.1 µg/l and four fish to 0.2 µg/l for 44 days. Although those in 0.2 µg/l convulsed frequently when disturbed, and those in 0.1 µg/l were very nervous, the mean blood concentration of each group was 0.18 and 0.25 µg/g with a range of 0.11 to 0.25 µg/g and 0.20 to 0.28 µg/g, respectively. These results indicate endrin is not stored in blood. Even in water containing concentrations of endrin that killed some fish and not others (partial kill

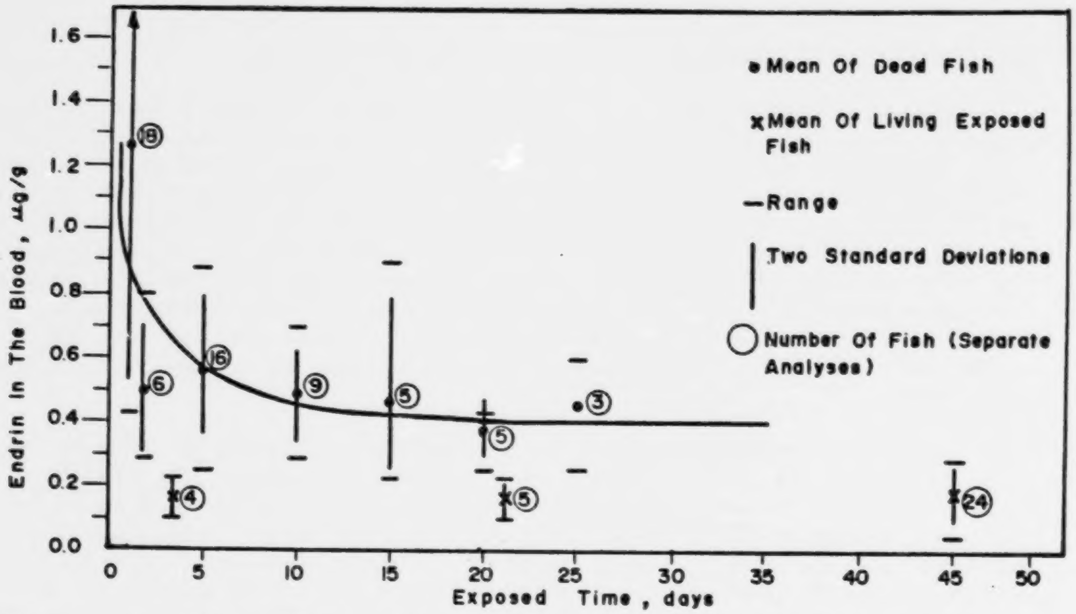

Figure F-1– The effect of time of exposure to endrin dissolved in water on the concentration of endrin in the blood of channel catfish.

and resulted either from insufficient time or because of individual variation), there was a distinct difference in the concentration of endrin in the blood of fish that were killed and those that were exposed but not killed. Figure F-1 shows some values for fish that survived exposure for 4, 21, and 44 days in water containing endrin concentrations that killed other fish in the same tank.

The results of this study indicate that the concentration of endrin in the circulating blood of channel catfish is related to intoxication and should be used as a diagnostic tool to determine the occurrence of endrin poisoning. No fish survived blood concentrations exceeding 0.28 μg/g and no fish died with less than 0.23 μg/g. Only five of 62 fish killed by endrin had less than 0.28 μg/g of endrin in the blood. If continuous exposure to endrin concentrations is not lethal in 44 days, longer exposure does not usually result in mortality (54). This method, therefore, should be applicable to fish kills resulting from endrin toxicity. Other studies (not yet published), have demonstrated that the critical blood concentration of endrin ranging from 0.23 to 0.28 μg/g for channel catfish is higher than for some other species of fish.

Endrin Concentrations in Blood of Gizzard Shad

Adult gizzard shad, 8 to 12 inches in length, were collected in April 1965 from Rocky Fork Lake by means of a fish trap utilized by the Ohio Division of Wildlife for fish population estimates. The shad were in these traps for up to 24 hours before being placed in holding tanks for transfer (50 miles) to the laboratory. These fish were observed and treated with antibiotic for two weeks before experimentation began. During this time and the additional two weeks of exposures there was less than 10 percent mortality due to causes other than endrin. Test procedures were similar to those for channel catfish.

Endrin concentrations in the blood of exposed living and killed shad related to time of exposure as shown in Table 6. Only blood from dead fish had endrin levels higher than 0.14 µg/g (average = 0.24) and only blood from live fish had concentrations of endrin less than 0.10 µg/g (average = 0.06). These results indicate a level of endrin in the blood of 0.10 µg/g at or above which very few gizzard shad could survive (in this study only 1 of 24 survived). The critical blood concentration for gizzard shad was found to range from 0.10 to 0.14 µg/g which is lower than that found for channel catfish.

Results of analyses of blood from field-exposed gizzard shad are included in the following table, F-1. Two composite blood samples, taken from 20 dead or dying shad during the fish kill in the Mississippi and Atchafalaya Rivers in 1963-64, had endrin levels of 0.15 and 0.22 µg/g. Ten blood samples taken from live shad collected in the same area one year later had endrin concentrations of 0.01 to 0.13 µg/g. Only one of these 12 samples did not agree with the aforementioned critical level of endrin in the blood of gizzard shad.

Table F-1. Concentrations of endrin in the blood of gizzard shad.

Condition and source	Number of Samples	Number of fish	Mean concentrations of endrin µg/g	Range
Dead, laboratory exposed	23	29	0.24	0.10 - 0.40
Dead, field exposed*	2	20	0.19	0.15 - 0.22
Live, laboratory exposed	8	10	0.06	0.01 - 0.14
Live, field exposed**	10	10	0.03	0.01 - 0.13

* Collected from Mississippi and Atchafalaya Rivers, 1963-1964.
** Collected from same general locations, Jan. - Feb., 1965.

EXHIBIT G

EFFECTS OF SUSPENDED SOLIDS ON ENDRIN TOXICITY TO FISH

The experiments reported here are an attempt to understand the effects of natural levels of suspended solids on the toxicity of endrin to fish.

Duplicate 96-hour tests were conducted under continuous-flow conditions utilizing natural water and fathead minnow. The experimental materials used were montmorillonite clay, Brookston silty clay loam, and activated carbon. The clay and soil were fractionated to remove particles larger than 2 microns (μ) so that settling of these materials in the testing apparatus would be reduced. All results are based on measurements of suspended solids and endrin concentrations in the water.

The experimental water was limestone spring water that was held in a 50,000 gallon surface reservoir with a retention time of 2 to 3 months. This water was heated by stainless steel immersion heaters in two connected constanthead chambers in the laboratory to maintain a temperature at 23° ± 1°C.

The 1 to 2 gram fathead minnows were raised in hatchery ponds at Newtown, Ohio. At least one month prior to the test, they were placed in holding aquaria receiving the same water as that used during the tests. During this time the fish were fed a dry trout food daily. At the start of each test, feeding of the fish was stopped and 10 fish were assigned randomly to each test chamber. Fish were exposed in stainless steel and glass chambers (63) under continuous-flow conditions by means of modification of the serial dilution apparatus (62).

A device similar to the toxicant metering system (62) was used to introduce the suspended solids into the test water at a calculated concentration of 50 mg/l. The aqueous stock suspension used for this system was continuously stirred to eliminate settling. After the solids had been introduced, this water passed on to the diluting system where endrin was added. The toxicant metering system introduced endrin with an average accuracy of 97 percent and a standard deviation of 3.1 percent. The flow rate resulted in renewal of the test water four times each day.

Most of the endrin in the water could be recovered by hexane extraction of the aqueous carbon suspensions. Consequently, 50 ml samples were collected from the test chamber overflows directly into calibrated centrifuge tubes. These samples were centrifuged for 10 minutes at 2,000 rpm and the supernatant water transferred to separatory funnels for routine extraction of endrin "in solution". Ten milliliters of acetone was added to the remaining carbon which was then mixed and centrifuged. The acetone was decanted into 100 ml of demineralized water in a separatory funnel. This rinse was then repeated. The water-acetone mixture was extracted with hexane as before. The average of the sum of endrin recoveries from both the water and carbon was 103 percent (101 to 105 percent).

Averages of analyses of two to four daily water samples, extracted just after collection, were used to calculate exposure levels that were then used to determine TL_m values graphically. In all, eleven tests were conducted from June 1965 to March 1966.

Suspended solids concentrations were determined twice during each test for each test chamber. A Beckman Model B Spectrophotometer at a wavelength of 500 millimicrons and standard curves prepared for each type of suspended solids were used. Replications of standards were within ± 2 percent ($\sim$ 1 mg/l). This technique is a modification of the standard method for measurement of turbidity (64).

The suspended solids used for the tests were the following: montmorillonite clay, 2 to 1μ and < 1μ size fractions; Brookston silty clay loam, < 2μ, and activated carbon, 40 to 1μ.

Since montmorillonite clay has the highest adsorption capacity of the common clay minerals (65), a form of montmorillonite (Wyoming bentonite) was used. This clay was fractionated by sedimentation of an aqueous suspension (66) to remove particles larger than 2μ, as a significant portion of clay particles larger than 2μ would have settled in the diluter and test chambers. To determine the effect of particle size, the montmorillonite was further fractionated into two sizes, 2-1μ and < 1μ, by means of a Serval superspeed centrifuge. The required flow rate and rpm were calculated for this centrifuge in order to retain one fraction in the centrifuge tubes and allow the < 1μ particles to remain in suspension. The resultant suspensions were assayed by oven-drying 50 ml aliquots, and diluted as required for the solids stocks.

Others have established that the availability of herbicides is reduced by soil organic matter (67 and 68), and similar results have been found for several chlorinated hydrocarbon insecticides (69-71). The Brookston silty clay loam was obtained from a pasture on the Ohio State University farm and was chosen because of its relatively high organic matter content. The soil was air-dried for 3 days, mixed, and a sample taken for toxicity tests; the water suspension was made by means of a Waring Blender. Sedimentation techniques (72) were again used to fractionate this soil suspension at 2µ; the resultant suspension was composed principally of clay and organic matter. This separation was not totally effective because of inadequate dispersal of the suspension; sufficient sodium carbonate to maintain a pH of 9.5 was used during sedimentation. This is the only soil dispersant that probably would not alter the soil for the toxicity tests. The resultant supernatant (∼< 2µ) was frozen until its use. Results of duplicate determinations of the organic content of the < 2µ fraction by a modification of the Chemical Oxygen Demand Method (63) were 11.4 and 11.6 percent.

Mineralogical characterization was performed by X-ray diffraction analysis using conventional methods and techniques. Cation-exchange capacity was determined by the method of Rich (73); the concentration of the displaced cation being determined by atomic absorption spectroscopy. Particle size distribution within the clay fraction of the Brookston soil was determined by the centrifugation method.

The results of the physio-chemical and mineralogical characterization can be seen in the following table, G-1. Although montmorillonite was found to be the predominant clay mineral in the Wyoming bentonite material, kaolinite and quartz were present as impurities; there being more kaolinite in the 2-1µ fraction than in the <1µ fraction. The diminution of the cation-exchange capacity in the 2-1µ fraction compared to the < 1µ fraction can be partly explained by the increase in the kaolinite content. Montmorillonite was the major clay mineral present in the soil clay. The majority of the clay fraction of the Brookston soil was found to be composed of the medium and/or fine clay size particles.

In general for a given clay, surface area increases as particle size decreases. Since both organic matter and montmorillonite have high surface areas as well as high cation-exchange capacities (68) and with the high proportion of the medium and/or fine clay sized particles, it would be expected that the soil would have a high potential adsorption capacity.

Several tests were conducted to determine endrin adsorption on the suspended < 2μ fraction of the Brookston soil. Samples of endrin-spiked water and soil (50 mg/l) were centrifuged at 2,000 rpm for one hour. The supernatant was transferred to a separatory funnel and the soil was resuspended in water. Both samples were then extracted with hexane; no endrin was recovered from the soil. Analysis of the supernatant yielded less than the initial endrin, however. During centrifugation, the temperature of the suspension reached 35°C. which may have caused partial volatilization or codistillation. Since this was not demonstrated, the results cannot be considered quantitatively conclusive. The absence of endrin on the soil does imply, however, that all the endrin in the test chambers was in solution and available to the test fish especially since recoveries of endrin from uncentrifuged water-soil-endrin mixtures were nearly 100 percent, as previously stated.

Table G-1. Physical, chemical, and mineralogical properties of the mineral adsorbents used.

Adsorbent	Mineralogical and character*	Cation-exchange capacity meq/100g	Particle size distribution percent 2-1μ	1-02μ	< 0.27	Organic matter percent
2-1μ Wyoming bentonite	M K Q**	75.1	-	-	-	-
< 1μ Wyoming bentonite	M K Q	81.9	-	-	-	-
< 2μ fraction of Brookston silty clay loam	M I K Q	33.9	14	20	66	11.5

* Estimates based upon X-ray diffraction, components listed in order of abundance.

M = montmorillonite; I = illite (mica); K = kaolinite (and halloysite); Q = quartz.

** Trace

The activated carbon was a 400-mesh water treatment carbon manufactured by the West Virginia Pulp and Paper Company. The average particle size was 11μ. Approximately 70 percent of the calculated carbon concentration was lost due to settling of these larger particles in the diluter and test chambers. Determinations of the suspended carbon and the amount of endrin associated with the carbon were based on the carbon in suspension, not on that which had settled in the test chambers. During the carbon tests, a fine mesh screen was placed in the bottoms of the test chambers so that the settled material would not be ingested by the fish.

The 96-hour TL_m results of the toxicity tests are listed in the following table, G-2. Originally, the study was planned to measure the effects of two size fractions of montmorillonite clay on endrin toxicity, and the duplicate tests were chronologically performed in random order. After these tests were completed, it was decided to conduct additional studies. The Analysis of Variance Method could only be used, therefore, for the four clay tests and the first two control tests. The results of this analysis of variance show no significant effects of either size fraction of montmorillonite clay on toxicity at the 95 percent confidence level (F-value = 4.66).

The TL_m values used in this statistical analysis ranged from 0.37 to 0.52 μg/1. Even though the toxicity tests with the Brookston soil fraction could not be included in this statistical analysis, the results (0.44 and 0.45 μg/1) indicate that this suspended solid also had no effect on endrin toxicity. On the other hand, the TL_m values for the carbon tests, in terms of total endrin present, were 18 and 26 μg/1 -- approximately 50 times the TL_m values for the other tests. Even without statistical verification this difference is obviously significant. When only the endrin found in solution is considered, however, the 96-hour TL_m results were 0.66 and 0.79 μg/1, which values are very similar to those for the other tests. All things considered, the only effect of the tested suspended solids on endrin toxicity to fathead minnows was the adsorption observed in the presence of carbon. Under test conditions carbon adsorbed approximately 95 percent of the total endrin present; the remaining 5 percent was the only endrin that contributed to toxicity.

Endrin was added after the solids were in suspension in the test water; consequently, test conditions more closely simulated industrial waste disposal rather than agricultural usage. Ferguson et al. (20) added soil to endrin solutions (the opposite sequence of the technique described above) and observed a possible delayed mortality of green sunfish (Lepomis

Table G-2. The effect of suspended solids on the toxicity of endrin to fathead minnows based on flow-through bioassay tests.

Test condition	96-hour TL Replicate 1 TL_m (µg/l)	 Replicate 2 TL_m (µg/l)
Control*	0.47	0.52
2-1u montmorillonite clay	0.50	0.47
< 1u montmorillonite clay	0.43	0.37
< 2u fraction of Brookston silty clay loam	0.44	0.45
Activated carbon dissolved	0.66	0.79
Total**	18.2	25.6
Control*, ***	0.45	---

* Control tests were those with no added suspended solids.

** Sum of dissolved and adsorbed endrin.

*** This was a test added at the end of the study to determine any effect of an increased hardness (300 mg/l as $CaCO_3$) on endrin toxicity.

cyanellus). They also mixed mud from a bayou that received runoff from cotton fields; this mud contained an average endrin concentration of 39 µg/kg. After a 28-day static test with mosquito fish and black bullhead (Ictalurus melas), they concluded that lethal amounts of endrin were not released into the standing water. They did detect, however, 0.1 µg/l of endrin per liter of water after 28 days; we determined in our laboratory that the 96-hour TL_m value for black bullhead was approximately 0.2 µg/l. Consequently, there might have been mortality due to endrin besides that which they attributed to putrefaction of the mud-water mixture. Although the results of their study are not very conclusive, they do indicate that the transfer of endrin from the mud to the water is not considerable.

Results of the Project study imply that when endrin is introduced into natural water in an unadsorbed state, its availability to fish is not greatly reduced unless a highly adsorptive material such as activated carbon is present. The data of Ferguson et al. (20) indicate that relatively high concentrations of endrin adsorbed on soil which is then introduced into water would contribute little to fish toxicity.

Because the hardness of the test water increased during our toxicity tests, an additional control test was conducted in water with a hardness of 300 mg/l as $CaCO_3$ to determine whether or not the increase in hardness from 149 mg/l affected toxicity. The TL_m values for the first control tests were 0.47 and 0.52 µg/l, and the repeat test value was 0.45 µg/l which indicate hardness had no effect on endrin toxicity. Henderson et al. (13) also demonstrated no effect of hardness on endrin toxicity to fathead minnows.

The results of this experiment and that of Ferguson et al. (20) indicate that the condition of endrin when it enters an aquatic environment is an important factor in determining its availability and, therefore, its potential toxicity to fish. The work of Ferguson et al. (20) indicates that only a small percentage of endrin associated with bottom sediments becomes available to fish in a short time. Conversely, if it is in solution its potential toxicity would probably be decreased only by the presence of a highly adsorptive material such as activated carbon.

EXHIBIT H

STATISTICAL EVALUATION OF SAMPLING DESIGN

In order to evaluate the effects of the compositing techniques, the 29 special series of samples on the Atchafalaya, Mississippi and Yazoo Rivers where the individual samples from the points in the cross section of the streams were analyzed separately for endrin were compared to the composite samples taken the same day. The mean of the endrin concentrations found in spatial-point samples on a given day were compared to the endrin concentration of the composite sample taken at the same time. The endrin concentration of the composite sample was higher than the mean of the spatial-point samples on 10 occasions while the concentration was lower than the mean of the spatial-point samples on 13 occasions. On six occasions concentrations were exactly the same for both types of samples. The weighted mean of the spatial-point samples of 0.05 µg/l of endrin was exactly the same as the mean of the composite samples.

A sign test ranking the pairs of the different types of samples was highly nonsignificant, P = .678, thus it is concluded that there were no biases in the compositing techniques used. However, this does not imply that the cross sectional type of sampling used is the most efficent and is necessary to measure concentrations of endrin in the bodies of water sampled.

The 29 special series of samples on the Atchafalaya, Mississippi and Yazoo Rivers where the individual samples from the points in the cross section of the streams were analyzed separately for endrin, were statistically analyzed to determine if there were any vertical or horizontal stratification of endrin in the stream cross section. An analysis of variance was performed on these data utilizing a two factor model, where deviation due to vertical and horizontal location of sample points were considered random factors. A transformation of the form,

$y = \log \quad (x + 0.001)$
where y = transformed data
and x = measure of concentration,

was used to normalize the distribution of the data. Occasionally a result from one of the verticals was missing and this value was estimated using the formula:

$$d = \frac{cT + rR - S}{(c-1)\ (r-1)}$$

Where d = estimated values,
c = number of verticals,
r = number of horizontals,
T = sum of existing values on the vertical with the missing value,
R = sum of existing values on the horizontal with the missing value,
and S = sum of all existing values.

The summary of the results of the analysis of variance is given in the following Table. The results of the analysis indicate that for the 29 experiments, there was only 1 significant difference found among different endrin concentrations between horizontal location and 4 between vertical locations in the cross section of the stream. In the number of comparisons made a certain number would be expected to be significant due to chance; and because of the large number of comparisons which were found to be nonsignificant, it is concluded that endrin is distributed randomly in the cross section of the stream.

Two experiments were conducted to determine if the mean endrin concentration at a point in the cross section of the rivers within a limited period of time differs from the mean of the points taken at the various depths from the verticals located at the centroids of equal segments of discharge in the cross section of the rivers.

On July 28, 1965 at the Memphis sampling station, twelve samples were collected at the 50 percent depth point at the vertical 730 feet from the left reference point of the cross section. Similarly on August 11, 1965 at the Vicksburg sampling station, eight samples were collected at the 50 percent depth point at the vertical 2310 feet from the right reference point. In both cases, the point-time samples were collected in the same time interval that the forty spatial-point samples were taken. Actually, because of field and laboratory accidents only 35 of the 40 spatial-point samples collected at Vicksburg were analyzed.

The mean endrin concentration for the point-time samples at the Memphis sampling station was 0.035 µg/l as compared to a mean of 0.028 µg/l for the spatial-point samples, while the mean endrin concentration for the point-time samples at the Vicksburg sampling station was 0.052 µg/l as compared to a

Table H-1. Summary of analysis of variance of 30 experiments to determine if there were vertical or horizontal stratification of endrin concentrations in the cross-sections of the rivers.

Sampling station and date	Vertical locations		Horizontal locations	
	F value	Degrees of freedom	F value	Degrees of freedom
Hickman				
Feb 27, 1965	1.00	4,28	1.00	7,28
Jul 19, 1965	0.38	4,24	1.75	6,24
Nov 12, 1965	0.59	4,28	1.99	7,28
May 6, 1966	1.10	5,35	1.50	7,35
Memphis				
Feb 15, 1965	1.64	4,27	2.00	7,27
Jul 28, 1965	0.34	4,28	0.79	7,28
Nov 18, 1965	0.19	4,28	2.92*	7,28
May 8, 1966	0.38	5,35	1.03	7,35
Vicksburg				
Mar 16, 1965	1.53	4,27	3.14*	4,27
Aug 11, 1965	1.00	4,22	0.30	6,22
Nov 21, 1965	1.64	4,28	2.34	4,28
May 11, 1966	0.18	5,33	1.90	7,33
Tarbert Landing				
May 3, 1965	0.51	4,28	0.71	7,28
Jul 26, 1965	3.40*	4,28	0.74	7,28
Dec 2, 1965	1.86	5,35	2.08	7,35
May 14, 1966	1.36	5,35	1.58	7,35
New Orleans				
Mar 24, 1965	0.44	4,28	1.85	7,28
June 2, 1965	0.71	4,28	2.21	7,28
Aug 12, 1965	1.26	5,35	1.14	7,35
Dec 7, 1965	0.86	5,35	9.60**	7,35
May 17, 1966	0.63	5,35	1.70	7,35
Simmesport				
May 19, 1965	2.26	4,16	0.67	4,16
Aug 4, 1965	1.90	5,20	0.26	4,20
Dec 8, 1965	0.33	5,20	1.37	4,20
May 18, 1966	1.22	5,20	0.33	4,20
Morgan City				
June 11, 1965	1.60	4,16	2.56	4,16
Dec 14, 1965	0.92	5,20	2.73	4,20
May 22, 1966	1.05	5,20	3.05*	4,20
Yazco				
April 9, 1965	1.08	4,16	1.05	4,16
Aug 12, 1965	0.18	4,16	1.17	4,16

* Significant at 0.05 probability level.

** Significant at 0.01 probability level.

mean of 0.051 µg/l for the spatial-point samples. To test the significance of the observed differences, a distribution free modified Mann-Whitney rank test was performed on the data. These tests yielded t-values of 0.975 and 0.139 for the Memphis and Vicksburg sampling stations, respectively. Both of these values are highly nonsignificant ($p > 0.2$ for Memphis sampling station and $p > 0.5$ for Vicksburg sampling station with ∞ degrees of freedom); therefore, the hypothesis that there are no differences between the mean of the point-time and spatial-point samples is accepted.

A somewhat different experiment concerning the variability of endrin concentrations with time at points in the cross section of the river was performed at the Tarbert Landing sampling station July 28, 1965. This experiment consisted of sampling five points, on the vertical 3667 feet from the right reference point of the cross section, at the end of the sampling of each vertical on the cross section. This resulted in eight values of endrin concentration for each of the 10, 30, 50, 70, and 90 percent depths on the vertical collected over a period of four hours. An analysis of variance was performed on these data utilizing a two factor model, where deviation due to depth sampled and time period sampled were considered random factors. Differences in concentration of endrin due to depth sampled were found to be nonsignificant at the 0.05 level of probability ($F = 0.411$, with 4 and 28 degrees of freedom); also, differences due to time period sampled were found to be nonsignificant ($F = 0.723$ with 7 and 28 degrees of freedom).

Within the limits of our sampling design and analytical procedure, no meaningful differences in endrin concentration could be demonstrated: 1. among horizontal or vertical locations in the cross section, 2. between different depths and over limited time periods or 3. between samples taken at one point in the river and stratified samples in the cross section. The sampling design used on the rivers is both costly and time consuming, and entails the use of cumbersome and expensive equipment; therefore, there would be important advantages, if samples for endrin, or for that matter, other types of material which act similar to endrin in a river environment, could be taken at any single point in the cross section of the river, with less elaborate equipment, and yield similar or nearly the same results. The analysis of these data would seem to indicate that this is the case; however, replication of samples for any one sampling period would be advantageous because of the inherent variability in such data.

EXHIBIT I

FISH SURVEY

Description of Sampling Stations

Five sampling stations were established on the Mississippi River in downstream sequence at Hickman, Kentucky; Tunica, Mississippi; Vicksburg, Mississippi; Tarbert Landing, Louisiana; and Luling, Louisiana, and two stations on the Atchafalaya River in downstream sequence in the vicinity of Simmesport and Morgan City, Louisiana (Fig. I-1). Differences in the area subject to overflow in the vicinity of the fish population sampling stations, as well as area of tributary streams, oxbows, sloughs, bayous, etc., affect the fish population present in the vicinity of the sampling stations on the Mississippi and Atchafalaya Rivers. Therefore, areas and numbers of different types of fish habitats within a 20 mile radius of the center of the fish population sampling station were estimated from U. S. Geological Survey Maps (Table I-1). Inasmuch as knowledge of the fish habitat sampled is necessary for interpretation of the sampling results, detailed descriptions of the sampling stations follow:

Hickman Station - This station, extending from river mile 920 to 926, is located near the Town of Hickman, Kentucky on the east side of the Mississippi River. Except for the flood plain area along the tributaries, the land on this side of the river is hilly while the west side of the river is low and flat. Gill and trammel nets were fished in slack water and eddies created by sandbars and river bends. Also, Obion Creek, entering the river at Hickman, affords many slack water areas near its mouth during most of the year. Hoop nets were fished in the river proper where current exists. There are approximately 31 square miles of water area within a 20 mile radius of the sampling station at river mile 923. The west side of the river is completely leveed, while the east side of the river is partially leveed.

Tunica Station - This station, extending from river mile 682 to 697, is located about 40 river miles down river from Memphis, Tennessee. The land area on both sides of the Mississippi River near this station is low and flat. Gill and trammel nets were fished in slack waters and eddies in

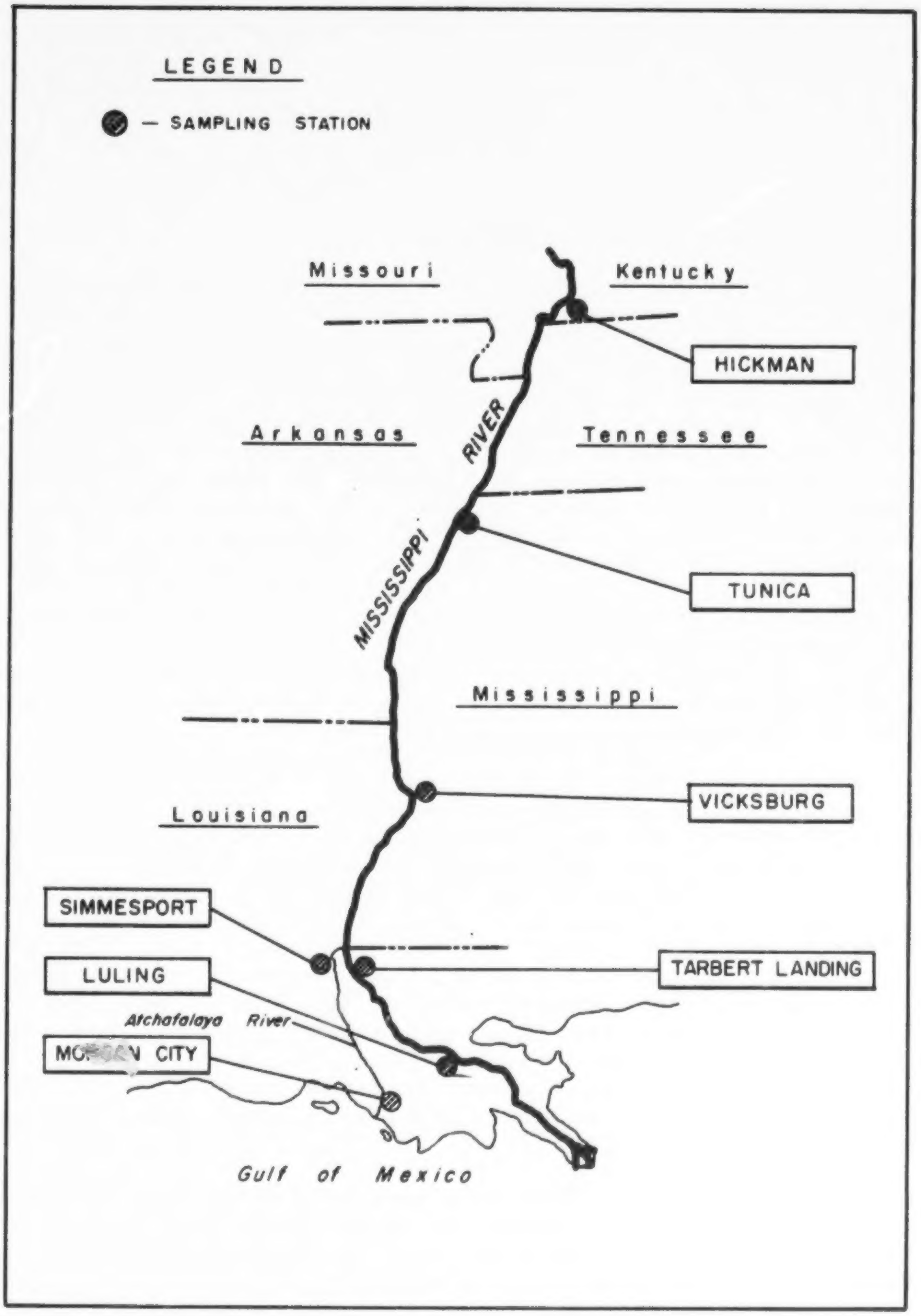
LEGEND
● — SAMPLING STATION
Missouri
Kentucky
HICKMAN
Arkansas
Tennessee
RIVER
MISSISSIPPI
TUNICA
Mississippi
VICKSBURG
Louisiana
SIMMESPORT
TARBERT LANDING
LULING
Atchafalaya River
MORGAN CITY
Gulf of Mexico

Figure I-1 Location of fish population sampling stations.

Table I-1. Area within a 20 mile radius from center of each fish population sampling station

	Sampling station						
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City
Square miles of water area in main river channel	31	22	14	22	10	5	45
Square miles of area subject to overflow	56	60	104	105	*	145	161
Miles of tributary streams	40	52	37	20	None	101	70
Miles of oxbows, sloughs, bayous, and small connecting streams	14	64	89	75	**	149	140

* No significant area subject to overflow.
** Only a few borrow pits.

two large sloughs and behind numerous sandbars. During extreme high and low water levels, the number of sampling sites were reduced. Since hoop nets are set in current, the river stage levels did not affect the number of sampling sites. Within a 20 mile radius of the sampling station at river mile 690, the Mississippi River is completely leveed on both sides, except for a short distance on the west side where the St. Francis River enters the Mississippi River.

Vicksburg Station - This station, extending from river mile 432 to 452, is located near the Town of Vicksburg, Mississippi. The east side of the Mississippi River near Vicksburg, is high and hilly; however, a few miles north of the city, as well as on the west side of the river, the land is low and flat. Gill and trammel nets were fished in slack water and eddies created by three large sloughs, sandbars, and river bends. Low water levels offered more sampling sites for ensnarement gear, i. e., gill and trammel nets, than did the high water levels. Hoop nets were fished in the river proper where current exists. Both sides of the Mississippi River within a 20-mile radius of the sampling station are completely leveed.

Tarbert Landing - This station, extending from river mile 300 to 310, is located at the Old River Locks on the west side of the Mississippi River. The nearest principal town on this side of the river is Simmesport, Louisiana located on the Atchafalaya River, a Mississippi River distributary. The flood plain of the river on the east side is rather narrow and is limited by the scarp bordering the higher lands. Gill and trammel nets were fished in slack water areas and eddies created by sloughs, riverbends and sandbars. Hoop nets were fished in the river proper where current exists. The west side of the Mississippi River is completely leveed within a 20-mile radius of the sampling station, however, there are no levees on the east side of the river. The escarpment on the east side of the river which separates the flood plain from the higher land serves as a natural levee.

Luling Station - This station, extending from river mile 117 to 125, is located near the Town of Luling, Louisiana, which is about 15 miles west (upstream) from New Orleans. A lack of sloughs and tributaries at the station restricts the use of gill and trammel nets to the slack waters and eddies behind riverbends and sandbars. Hoop nets were fished in the river proper where current exists. Within a 20-mile radius of the sampling station at river mile 121, the Mississippi is completely leveed on both sides. Only a narrow strip of overflow land lies between the levees. There are a few scattered borrow pits in this strip.

Simmesport Station - This sampling station, extending from river mile 0 at the confluence of the Mississippi and Red Rivers to river mile 6, is located on the Atchafalaya River near the Town of Simmesport, Louisiana. Approximately 40 percent of the volume of water from the Mississippi River in this area is directed to the Atchafalaya River. Gill and trammel nets were fished in eddies, small slack water bays and the mouth of a dredged cut, while hoop nets were set in the river proper where current exists. The river is completely leveed from Simmesport to the lower end of the 20-mile radius of the sampling station. However, north of Simmesport the upper end of the Atchafalaya Basin is subject to overflow.

Morgan City Station - This sampling station, extending parallel from river mile 97 to 103 on the main channel of the Atchafalaya River, is located in Grand Lake about 14 miles northeast of Morgan City, Louisiana. Grand Lake is one of a series of lakes through which the Atchafalaya River passes on its course to the nearby Gulf of Mexico. Gill and trammel nets were generally set in the slack waters behind the sandbars near Windy Point on Grand Lake or downstream from the bends on the lakeshore at Willow Cove. Hoop nets were set in channels where current existed. Both sides of the Atchafalaya River Basin are leveed but there are relatively large areas of floodplain, approximately 161 square miles, contained within the leveed area subject to overflow. Pronounced tidal effects are noticeable within the sample area, with upstream currents occurring during incoming tides.

Materials and Methods

Fish population samples were taken by project biologists and a commercial fisherman who lived and fished commercially in the general area of the sampling station. Samples were taken during eight sampling periods per year. A standard amount of gear was fished for a five-day period during each sampling period. The sampling included 2 experimental gill nets, 6 trammel nets and 8 hoop nets, descriptions of which are given in Table I-2.

Gill and trammel nets are fished in eddies or slack waters, either behind sandbars, in mouths of sloughs or downstream from river bends. Hoop nets are set in flowing waters with sufficient velocity to keep the nets upright.

The commercial fishermen's knowledge of the area and experience with the type of gear used were fully utilized during the survey. All gear was fished for 24 hours before it was checked or moved. The nets were moved daily if fish were not being caught since the maximum catch of all species was desired. Total lengths of captured fish were determined to the nearest inch. Each species was grouped according to size, counted, and then weighed collectively in pounds.

The unit of measurement employed in determining the abundance of fish in the catch was the number of pounds of fish caught per net day, where a net day represents 24 hours of fishing effort by a hoop, gill or trammel net. Occasionally a net would be lost, tampered with or torn up by drift or

Table I-2. Sampling gear used to sample fish population during each five day sampling period.

No. of nets	Type	Square mesh size (inches)	Length (feet)
2	Experimental gill nets	.75 - 2.5*	125
2	Trammel nets	1.5	150
2	Trammel nets	2.5	150
2	Trammel nets	3.5	150
2	Hoop nets	.75 (tail)	-
2	Hoop nets	1 (tail)	-
2	Hoop nets	2 (tail)	-
2	Hoop nets	3 (tail)	-

* Each experimental gill net contains the following square mesh sizes in 25 foot sections: .75 inch, 1 inch, 1.5 inch, 2 inches, and 2.5 inches.

boats in the river. Therefore, in order to give equal weight to each net type, and mesh size, the total number or pounds of fish caught per net day was calculated for each type of net and mesh size by sampling periods, e. g., the catch per net day for 1.5 inch square mesh trammel net for period 1 and the catch per net day for 2.5 inch square net trammel nets for period 1. The catch rate for each type of gear for a sampling period was obtained by averaging the catch rates for the various mesh sizes (i. e., the 3 mesh sizes of trammel nets and the 4 mesh sizes of hoop nets). A mean catch rate for each sampling period was determined by averaging the catch rates for the three types of sampling gear. Mean catch by type of net for year and for all sampling stations was determined by averaging the catch rates for the periods and stations, respectively. Similar procedures were used for determining the catch rates for individual species of fish. Thus, each type of gear and sampling period was given equal weight in determining overall averages.

Fish captured were separated into two main groups, predacious and nonpredacious (refer to Tables I-3 through I-4b). Predacious fish includes those types of fish that usually feed on other fish and large aquatic forage animals, while nonpredacious fish are those that normally do not. All species of fish that sportsmen normally seek were grouped under the heading of game fish while fish that are regularly or occasionally sold commercially were classed as commercial. (Tables I-3 through I-4b).

Bigmouth buffalo, smallmouth buffalo, black buffalo, and carpsuckers were considered to be of harvestable size when they had a total length of 16 inches and over. Twelve inches and over were considered to be a harvestable size for freshwater drum and catfishes.

Results & Discussion

Species Occurrence. A total of 63 species of fish were caught at the seven stations on the Mississippi and Atchafalaya Rivers (Tables I-3 through I-4b). A total of 25 predacious and 38 nonpredacious species were represented in the collections while 16 game and 28 commercial species were represented. (Table 1-3 through I-4b).

Undoubtedly other species of fish were present in the rivers; however, it is believed that all of the large species of fish which were found in any abundance in the vicinity of the sampling stations were represented in the collections. Because of the types of sampling gear used, which were not very efficient in catching the smaller species of fish, such as the minnows, the data presented are not indicative of the occurrence of the smaller species in the rivers.

Tables I-8, I-8a, and I-8b show the number of fish caught per net day for 23 of the more abundant species. Gizzard shad was the most abundant species at most of the sampling stations. As might be expected, some species which occur typically in a marine or estuarine habitat, were abundant at the downstream stations and were absent at the upstream stations.

Of particular interest was the abundance of some species of game fish, especially white bass, yellow bass, and white crappie. These data indicate a potential exists for a sports fishery on the Mississippi River comparable to that which now exists on the lower section of the Atchafalaya River.

Commercial fish were abundant at all sampling stations, especially freshwater drum, blue catfish, channel catfish, and smallmouth buffalo (Tables I-8, I-8a, and I-8b) and a large percent of the commercial fish was of harvestable size.

Examination of length frequencies of the fish caught showed that for the most part an adequate representation of different sizes of fish occurred in the population. There appeared to be, however, an apparent paucity of fish in the larger size groups of the more long-lived species.

It is concluded that a favorable commercial and sport fish population now exists in the Mississippi and Atchafalaya Rivers. It is also concluded that no catastrophy, such as the 1963-64 fish kills has occurred since the fall of 1963 and early winter of 1964.

Comparison of Sampling Gear. Experimental gill nets caught the greatest number of fish per net day at all seven sampling stations (Table I-5, I-5a, I-5b, and Figures I-2, I-2a, I-2b) while trammel nets caught the greatest poundage of fish per net day at all stations (Tables I-6, I-6a, I-6b and Figures I-3, I-3a, I-3b). Generally this was also true for individual species of fish, with some exceptions. The number of carp, smallmouth buffalo, and river carpsuckers caught per net day by trammel nets was on the average greater than that caught by other types of gear, while the number of gizzard shad, threadfin shad, white bass, yellow bass, channel catfish, and white crappie caught per net day by gill nets was on the average greater than that caught by other types of gear (Tables I-8, I-8a, I-8b).

Both gill and trammel nets were efficient in sampling the fish populations in the rivers. Hoop nets were a relatively inefficient sampling gear in the rivers, and catch rates could not be equated to the catch rate of the gill or trammel nets.

Abundance of Fish. The mean catch rates (number of fish caught per net day) are depicted graphically in Figures I-2, I-2a, and I-2b by station, by type of gear, by year. These results are further summarized in Figure I-4 in which the annual mean catch rates for all gear at each station by year are shown along with an overall three year mean. This latter presentation of the data shows that the Simmesport station produced the greatest number of fish per net day during the three year period with the Luling station second. The stations with the poorest three year mean catch rates were Tunica and Vicksburg. On the Mississippi River, with the exception of Hickman and beginning with Tunica in a downstream sequence, the mean number of fish per net day increases to a maximum at Luling. On the Atchafalaya River the number decreases from Simmesport to Morgan City. The least number of fish caught per net day during an individual year was at Morgan City during 1968. The greatest mean catch rate during an individual year was at Luling during 1967.

Figures I-3, I-3a, and I-3b, present a summary of all data similar to that discussed above but in terms of mean pounds of fish caught per net day. Figure 1-5 corresponds to Figure 1-4 and shows annual mean-pounds of fish caught per net day for all gear at each of the seven stations for each fishing year along with a three-year mean for all stations. In terms of three-year mean-pounds per net day the Hickman station was first and Simmesport second. The three-year mean-pounds per net day decreases progressively by station from Hickman to Tarbert Landing but rises sharply at Luling. On the Atchafalaya River, the Simmesport station mean catch per net day in terms of a three-year mean is considerably larger than that at Morgan City. The pounds per net day showed the least variation at the Hickman, Tunica, and Vicksburg stations.

Table I-3 Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1966.

	Sampling Stations							
Common and scientific names	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
Predacious fish								
*Largemouth Bass, *Micropterus salmoides*	5	5	1	16	14	9	10	60
*White Bass, *Roccus chrysops*	83	21	120	108	22	288	39	681
*Yellow Bass, *Roccus mississippiensis*	107	5	2	18	70	110	61	373
Bowfin, *Amia calva*	3	4	1	38	18	39	26	129
**Blue Catfish, *Ictalurus furcatus*	115	142	311	496	214	434	69	1781
**Channel Catfish, *Ictalurus punctatus*	103	164	34	211	456	144	183	1295
**Flathead Catfish, *Pylodictis olivaris*	43	44	87	51	3	68	10	306
*Black Crappie, *Pomoxis nigromaculatus*	24	56	13	142	78	115	30	458
*White Crappie, *Pomoxis annularis*	201	260	110	205	30	246	32	1084
**Flounder, *Paralichthys sp*	0	0	0	0	85	12	4	101
**Alligator Gar, *Lepisosteus spatula*	0	0	0	2	3	16	9	30
**Longnosed Gar, *Lepisosteus osseus*	136	33	26	22	1	196	81	495
**Shortnosed Gar, *Lepisosteus platostomus*	1339	349	250	345	30	1238	158	3709
Spotted Gar, *Lepisosteus oculatus*	2	0	3	27	33	50	655	770
*Sauger, *Stizostedion canadense*	104	74	30	30	0	61	1	300
American Eel, *Anguilla rostrata*	0	0	2	1	2	3	10	18
*Chain Pickerel, *Esox niger*	1	0	0	0	0	2	0	3
Atlantic Needlefish, *Strongylura marina*	0	0	0	0	1	1	1	3
*Northern Pike, *Esox lucius*	0	2	0	0	0	0	0	2
*Gaff Topsail Catfish, *Bagre marinus*	0	0	0	0	7	0	0	7
Ladyfish, *Elops saurus*	0	0	0	0	33	0	1	34
*Crevalle Jack, *Caranx hippos*	0	0	0	0	3	0	0	3
*Silver Sea Trout, *Cynoscion nothus*	0	0	0	0	2	0	0	2
Horse Eye Jack, *Caranx latus*	0	0	0	0	1	0	0	1
*Spotted Bass, *Micropterus punctulatus*	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-3 Continued Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1966.

Non-predacious fish								
**Bigmouth Buffalo, *Ictiobus cyprinellus*	96	121	85	136	145	131	24	738
**Black Buffalo, *Ictiobus niger*	43	33	32	51	75	19	17	270
**Smallmouth Buffalo, *Ictiobus bubalus*	191	109	341	204	308	151	580	1884
*Bluegill, *Leopmis macrochirus*	17	12	9	31	6	10	6	91
**Brown Bullhead, *Ictalurus nebulosus*	0	0	0	1	7	15	1	24
**Black Bullhead, *Ictalurus melas*	3	9	1	5	10	13	3	44
**Yellow Bullhead, *Ictalurus natalis*	0	0	1	1	2	5	14	23
**Carp, *Cyprinus carpio*	250	277	123	493	370	136	107	1756
**Quillback Carpsucker, *Carpiodes cyprinus*	7	18	1	0	0	0	1	27
**River Carpsucker, *Carpiodes carpio*	862	528	322	308	8	342	17	2387
Sea Catfish, *Galeichthys felis*	0	0	0	0	37	0	0	37
Pirate Perch, *Aphredoderus sayanus*	0	1	0	0	0	0	0	1
**Fresh-Water Drum, *Aplodinotus grunniens*	246	163	331	285	196	325	100	1646
Goldeye, *Hiodon alosoides*	118	71	35	33	1	372	1	631
Skipjack Herring, *Alosa chrysochloris*	142	93	287	128	443	311	37	1441
Mooneye, *Hiodon tergisus*	0	25	0	1	0	3	0	29
**Silver Mullet, *Mugil curema*	0	0	0	0	0	1	0	1
**Striped Mullet, *Mugil cephalus*	0	0	1	20	131	76	1425	1653
**Paddlefish, *Polyodon spathula*	13	25	22	15	1	16	7	99
Gizzard Shad, *Dorosoma cepedianum*	1679	1679	1234	1750	1185	2144	1382	11053
Threadfin Shad, *Dorosoma petenense*	23	71	154	212	715	237	28	1440
Golden Shiner, *Notemigonus crysoleucas*	0	1	1	0	0	0	5	7
**Shovelnose Sturgeon, *Scaphirhynchus platorynchus*	81	2	1	0	0	1	0	85
*Longear Sunfish, *Lepomis megalotis*	9	10	0	3	0	3	0	25
*Redear Sunfish, *Lepomis microlophus*	0	0	0	2	0	1	7	10
*Warmouth, *Chaenobryttus gulosus*	2	0	0	4	1	2	7	16
**Spotted Sucker, *Minytrema melanops*	0	2	1	7	0	1	2	13
Hogchoker, *Trinectes maculatus*	0	0	0	0	0	1	12	13
**Blue Sucker, *Cycleptus elongatus*	0	1	8	0	0	1	0	10
**Chub Sucker, *Erimyzon sp*	0	0	0	0	0	2	2	4
Flathead Chub, *Hybopsis gracilis*	0	1	0	0	0	0	0	1
Silver Chub, *Hybopsis storeriana*	0	0	2	0	0	0	0	2
**Golden Redhorse, *Moxostoma erythrurum*	0	0	1	0	0	0	0	1
**Menhaden, *Brevoortia patronus*	0	0	0	0	784	4	24	812
**Croaker, *Micropogon undulatus*	0	0	0	0	1	0	0	1
**Spot, *Leiostomus xanthurus*	0	0	0	0	2	0	0	2
Blunt Nose Stingray, *Dasyatis sayi*	0	0	0	0	3	0	0	3
Flier, *Centrarchus necropterus*	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-3 Continued Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1966.

Non-predacious fish								
**Bigmouth Buffalo, Ictiobus cyprinellus	96	121	85	136	145	131	24	738
**Black Buffalo, Ictiobus niger	43	33	32	51	75	19	17	270
**Smallmouth Buffalo, Ictiobus bubalus	191	109	341	204	308	151	580	1884
*Bluegill, Leopmis macrochirus	17	12	9	31	6	10	6	91
**Brown Bullhead, Ictalurus nebulosus	0	0	0	1	7	15	1	24
**Black Bullhead, Ictalurus melas	3	9	1	5	10	13	3	44
**Yellow Bullhead, Ictalurus natalis	0	0	1	1	2	5	14	23
**Carp, Cyprinus carpio	250	277	123	493	370	136	107	1756
**Quillback Carpsucker, Carpiodes cyprinus	7	18	1	0	0	0	1	27
**River Carpsucker, Carpiodes carpio	862	528	322	308	8	342	17	2387
Sea Catfish, Galeichthys felis	0	0	0	0	37	0	0	37
Pirate Perch, Aphredoderus sayanus	0	1	0	0	0	0	0	1
**Fresh-Water Drum, Aplodinotus grunniens	246	163	331	285	196	325	100	1646
Goldeye, Hiodon alosoides	118	71	35	33	1	372	1	631
Skipjack Herring, Alosa chrysochloris	142	93	287	128	443	311	37	1441
Mooneye, Hiodon tergisus	0	25	0	1	0	3	0	29
**Silver Mullet, Mugil curema	0	0	0	0	0	1	0	1
**Striped Mullet, Mugil cephalus	0	0	1	20	131	76	1425	1653
**Paddlefish, Polyodon spathula	13	25	22	15	1	16	7	99
Gizzard Shad, Dorosoma cepedianum	1679	1679	1234	1750	1185	2144	1382	11053
Threadfin Shad, Dorosoma petenense	23	71	154	212	715	237	28	1440
Golden Shiner, Notemigonus crysoleucas	0	1	1	0	0	0	5	7
**Shovelnose Sturgeon, Scaphirhynchus platorynchus	81	2	1	0	0	1	0	85
*Longear Sunfish, Lepomis megalotis	9	10	0	3	0	3	0	25
*Redear Sunfish, Lepomis microlophus	0	0	0	2	0	1	7	10
*Warmouth, Chaenobryttus gulosus	2	0	0	4	1	2	7	16
**Spotted Sucker, Minytrema melanops	0	2	1	7	0	1	2	13
Hogchoker, Trinectes maculatus	0	0	0	0	0	1	12	13
**Blue Sucker, Cycleptus elongatus	0	1	8	0	0	1	0	10
**Chub Sucker, Erimyzon sp	0	0	0	0	0	2	2	4
Flathead Chub, Hybopsis gracilis	0	1	0	0	0	0	0	1
Silver Chub, Hybopsis storeriana	0	0	2	0	0	0	0	2
**Colden Redhorse, Moxostoma erythrurum	0	0	1	0	0	0	0	1
**Menhaden, Brevoortia patronus	0	0	0	0	784	4	24	812
**Croaker, Micropogon undulatus	0	0	0	0	1	0	0	1
**Spot, Leiostomus xanthurus	0	0	0	0	2	0	0	2
Blunt Nose Stingray, Dasyatis sayi	0	0	0	0	3	0	0	3
Flier, Centrarchus necropterus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-3 Continued Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1966.

	Sampling Stations							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
TOTAL	6048	4411	3983	5402	5537	7355	5189	37925
Game Fish	553	445	285	559	233	847	193	3115
Non-Game Fish	5495	3966	3698	4843	5304	6508	4996	34810
Commercial Fish	3528	2020	1979	2653	2832	3347	2838	19197
Non-Commercial Fish	2520	2391	2004	2749	2705	4008	2351	18728

Table I-3a Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1967.

	Sampling Stations							
Common and scientific names	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
Predacious fish								
*Largemouth Bass, Micropterus salmoides	0	3	10	4	10	14	9	50
*White Bass, Roccus chrysops	139	26	71	129	47	170	113	695
*Yellow Bass, Roccus mississippiensis	46	5	7	32	53	79	43	265
Bowfin, Amia calva	2	3	0	13	18	11	10	57
**Blue Catfish, Ictalurus furcatus	30	161	161	600	382	249	40	1623
**Channel Catfish, Ictalurus punctatus	81	90	90	122	526	51	104	1064
**Flathead Catfish, Pylodictis olivaris	29	42	74	40	0	27	0	212
*Black Crappie, Pomoxis nigromaculatus	6	12	70	29	47	49	38	251
*White Crappie, Pomoxis annularis	60	107	272	94	43	175	44	795
**Flounder, Paralichthys sp	0	0	0	0	35	0	5	40
**Alligator Gar, Lepisosteus spatula	0	1	0	0	3	6	13	23
**Longnosed Gar, Lepisosteus osseus	76	28	23	12	4	99	30	272
**Shortnosed Gar, Lepisosteus platostomus	643	158	162	179	29	431	155	1757
Spotted Gar, Lepisosteus oculatus	0	0	3	13	8	21	636	681
*Sauger, Stizostedion canadense	105	194	73	28	4	45	2	451
American Eel, Anguilla rostrata	2	0	0	0	0	0	1	3
*Chain Pickerel, Esox niger	0	0	0	1	0	1	0	2
Atlantic Needlefish, Strongylura marina	0	0	0	0	0	1	0	1
*Northern Pike, Esox lucius	1	0	0	0	0	0	0	1
*Gaff Topsail Catfish, Bagre marinus	0	0	0	0	0	0	0	0
Ladyfish, Elops saurus	0	0	0	0	6	0	0	6
*Crevalle Jack, Caranx hippos	0	0	0	0	0	0	0	0
*Silver Sea Trout, Cynoscion nothus	0	0	0	0	0	0	0	0
Horse Eye Jack, Caranx latus	0	0	0	0	0	0	0	0
*Spotted Bass, Micropterus punctulatus	0	0	1	0	0	0	0	1

*Game Fish
**Commercial Fish

Table I-3a Continued Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1967.

Non-predacious fish								
**Bigmouth Buffalo, Ictiobus cyprinellus	22	53	54	44	147	77	26	423
**Black Buffalo, Ictiobus niger	41	26	8	16	72	17	5	185
**Smallmouth Buffalo, Ictiobus bubalus	149	180	158	86	353	217	497	1640
*Bluegill, Leopmis macrochirus	4	5	14	12	11	0	31	77
**Brown Bullhead, Ictalurus nebulosus	0	2	2	2	0	1	0	7
**Black Bullhead, Ictalurus melas	0	1	0	0	4	5	2	12
**Yellow Bullhead, Ictalurus natalis	0	0	0	0	2	2	3	7
**Carp, Cyprinus carpio	123	79	90	109	371	87	68	927
**Quillback Carpsucker, Carpiodes cyprinus	6	32	0	0	0	0	0	38
**River Carpsucker, Carpiodes carpio	967	1424	658	326	30	416	10	3831
Sea Catfish, Galeichthys felis	0	0	0	0	5	0	0	5
Pirate Perch, Aphredoderus sayanus	0	0	1	0	0	0	0	1
**Fresh-Water Drum, Aplodinotus grunniens	220	282	247	419	252	209	130	1759
Goldeye, Hiodon alosoides	155	54	21	34	1	116	6	387
Skipjack Herring, Alosa chrysochloris	94	99	149	327	721	355	28	1773
Mooneye, Hiodon tergisus	4	5	1	0	0	0	0	10
**Silver Mullet, Mugil curema	0	0	0	0	0	0	0	0
**Striped Mullet, Mugil cephalus	0	0	4	6	279	121	1271	1681
**Paddlefish, Polyodon spathula	6	21	3	62	1	6	0	99
Gizzard Shad, Dorosoma cepedianum	1086	1080	2365	1329	1759	2546	1381	11546
Threadfin Shad, Dorosoma petenense	20	72	178	551	880	250	18	1969
Golden Shiner, Notemigonus crysoleucas	0	0	4	0	0	0	0	4
**Shovelnose Sturgeon, Scaphirhynchus platorynchus	3	9	2	0	0	3	0	17
*Longear Sunfish, Lepomis megalotis	3	24	0	0	0	0	1	28
*Redear Sunfish, Lepomis microlophus	0	0	0	0	2	0	13	15
*Warmouth, Chaenobryttus gulosus	0	0	1	0	1	0	4	6
**Spotted Sucker, Minytrema melanops	0	1	0	2	0	2	0	5
Hogchoker, Trinectes maculatus	0	0	0	0	0	0	5	5
**Blue Sucker, Cycleptus elongatus	1	2	2	1	0	2	0	8
**Chub Sucker, Erimyzon sp	0	0	0	0	0	0	0	0
Flathead Chub, Hybopsis gracilis	0	0	0	0	0	0	0	0
Silver Chub, Hybopsis storeriana	0	0	0	0	0	0	0	0
**Golden Redhorse, Moxostoma erythrurum	0	0	0	0	0	0	0	0
**Menhaden, Brevoortia patronus	0	0	0	0	89	0	1	90
**Croaker, Micropogon undulatus	0	0	0	0	1	0	0	1
**Spot, Leiostomus xanthurus	0	0	0	0	0	0	0	0
Blunt Nose Stingray, Dasyatis sayi	0	0	0	0	0	0	0	0
Flier, Centrarchus necropterus	0	0	0	0	0	1	0	1

*Game Fish
**Commercial Fish

Table I-3a Continued Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1967.

	Sampling Stations							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
TOTAL	4124	4281	4979	4622	6196	5862	4743	34807
Game Fish	364	376	519	329	218	533	298	2637
Non-Game Fish	3760	3905	4460	4293	5978	5329	4445	32170
Commercial Fish	2397	2592	1738	2026	2580	2028	2360	15721
Non-Commercial Fish	1727	1689	3241	2596	3616	3834	2383	19086

Table I-3b Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1968.

Common and scientific names	Sampling Stations							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
Predacious fish								
*Largemouth Bass, Micropterus salmoides	7	4	3	6	6	16	12	54
*White Bass, Roccus chrysops	134	14	78	61	26	78	67	458
*Yellow Bass, Roccus mississippiensis	39	3	6	20	9	6	54	137
Bowfin, Amia calva	1	0	13	7	4	8	23	56
**Blue Catfish, Ictalurus furcatus	110	80	175	345	387	194	71	1362
**Channel Catfish, Ictalurus punctatus	106	61	37	101	575	90	56	1026
**Flathead Catfish, Pylodictis olivaris	22	29	61	31	1	14	6	164
*Black Crappie, Pomoxis nigromaculatus	2	10	46	26	2	37	54	177
*White Crappie, Pomoxis annularis	53	57	207	134	40	213	15	719
**Flounder, Paralichthys sp	0	0	0	0	16	0	2	18
**Alligator Gar, Lepisosteus spatula	0	0	0	0	6	16	7	29
**Longnosed Gar, Lepisosteus osseus	45	32	14	5	5	60	30	191
**Shortnosed Gar, Lepisosteus platostomus	1064	137	202	150	4	298	89	1944
Spotted Gar, Lepisosteus oculatus	0	0	1	16	3	18	379	417
*Sauger, Stizostedion canadense	139	143	30	12	2	28	2	356
American Eel, Anguilla rostrata	1	0	0	0	0	0	2	3
*Chain Pickerel, Esox niger	0	0	0	0	0	0	0	0
Atlantic Needlefish, Strongylura marina	0	0	0	0	0	0	0	0
*Northern Pike, Esox lucius	0	0	0	0	0	0	0	0
*Gaff Topsail Catfish, Bagre marinus	0	0	0	0	0	0	0	0
Ladyfish, Elops saurus	0	0	0	0	0	0	0	0
*Crevalle Jack, Caranx hippos	0	0	0	0	0	0	0	0
*Silver Sea Trout, Cynoscion nothus	0	0	0	0	0	0	0	0
Horse Eye Jack, Caranx latus	0	0	0	0	0	0	0	0
*Spotted Bass, Micropterus punctulatus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-3b Continued Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1968.

Non-predacious fish								
**Bigmouth Buffalo, Ictiobus cyprinellus	26	44	68	36	142	68	17	401
**Black Buffalo, Ictiobus niger	35	12	2	16	3	11	10	89
**Smallmouth Buffalo, Ictiobus bubalus	88	68	148	68	182	323	265	1142
*Bluegill, Leopmis macrochirus	7	24	22	11	2	27	13	106
**Brown Bullhead, Ictalurus nebulosus	0	0	2	0	1	1	4	8
**Black Bullhead, Ictalurus melas	4	0	0	0	1	0	0	5
**Yellow Bullhead, Ictalurus natalis	0	0	3	0	0	1	2	6
**Carp, Cyprinus carpio	169	108	209	119	199	104	97	1005
**Quillback Carpsucker, Carpiodes cyprinus	21	9	0	0	0	0	0	30
**River Carpsucker, Carpiodes carpio	924	1223	610	216	20	736	13	3742
Sea Catfish, Galeichthys felis	0	0	0	0	2	0	0	2
Pirate Perch, Aphredoderus sayanus	0	0	1	0	0	0	0	1
**Fresh-Water Drum, Aplodinotus grunniens	236	192	89	175	254	249	87	1282
Goldeye, Hiodon alosoides	270	72	54	13	0	26	1	436
Skipjack Herring, Alosa chrysochloris	63	139	376	101	333	423	4	1439
Mooneye, Hiodon tergisus	4	7	1	0	1	2	1	16
**Silver Mullet, Mugil curema	0	0	0	0	2	5	0	7
**Striped Mullet, Mugil cephalus	0	0	1	8	202	112	683	1006
**Paddlefish, Polyodon spathula	20	30	11	88	1	59	3	212
Gizzard Shad, Dorosoma cepedianum	1202	1057	1509	766	631	1209	597	6971
Threadfin Shad, Dorosoma petenense	7	128	489	633	74	381	15	1727
Golden Shiner, Notemigonus crysoleucas	0	18	3	0	0	0	0	21
**Shovelnose Sturgeon, Scaphirhynchus platorynchus	2	8	1	0	2	3	0	16
*Longear Sunfish, Lepomis megalotis	2	4	0	0	0	0	0	6
*Redear Sunfish, Lepomis microlophus	0	0	0	0	0	4	3	7
*Warmouth, Chaenobryttus gulosus	0	1	0	1	0	12	12	26
**Spotted Sucker, Minytrema melanops	0	2	0	0	2	1	0	5
Hogchoker, Trinectes maculatus	0	0	0	0	0	0	2	2
**Blue Sucker, Cycleptus elongatus	0	0	0	0	0	0	0	0
**Chub Sucker, Erimyzon sp	9	13	0	0	0	0	0	22
Flathead Chub, Hybopsis gracilis	0	0	0	6	0	0	1	7
Silver Chub, Hybopsis storeriana	2	20	0	0	0	0	0	22
**Golden Redhorse, Moxostoma erythrurum	1	0	0	0	0	0	0	1
**Menhaden, Brevoortia patronus	0	0	0	0	37	0	2	39
**Croaker, Micropogon undulatus	0	0	0	0	0	0	0	0
**Spot, Leiostomus xanthurus	0	0	0	0	0	0	0	0
Blunt Nose Stingray, Dasyatis sayi	0	0	0	0	1	0	0	1
Flier, Centrarchus necropterus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-3b Continued Total number of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers during eight fishing periods in 1968.

	Sampling Stations							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
TOTAL	4815	3749	4472	3171	3178	4833	2701	26919
Game Fish	383	260	392	271	87	421	232	2046
Non-Game Fish	4432	3489	4080	2900	3091	4412	2469	24873
Commercial Fish	2882	2048	1633	1358	2042	2345	1444	13752
Non-Commercial Fish	1933	1701	2839	1813	1136	2488	1257	13167

Table I-4 Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1966.

	Sampling Stations							
Common and scientific names	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
Predacious fish								
*Largemouth Bass, Micropterus salmoides	8	6	1	20	14	5	7	61
*White Bass, Roccus chrysops	73	19	150	102	23	238	23	628
*Yellow Bass, Roccus mississippiensis	33	1	0	2	34	32	15	117
Bowfin, Amia calva	25	23	4	102	50	122	165	491
**Blue Catfish, Ictalurus furcatus	245	108	197	264	81	365	48	1308
**Channel Catfish, Ictalurus punctatus	154	178	52	114	177	69	99	843
**Flathead Catfish, Pylodictis olivaris	123	125	267	135	10	172	25	857
*Black Crappie, Pomoxis nigromaculatus	12	21	7	67	45	53	12	217
*White Crappie, Pomoxis annularis	108	139	56	97	13	143	9	565
**Flounder, Paralichthys sp	0	0	0	0	141	7	10	158
**Alligator Gar, Lepisosteus spatula	0	0	0	35	57	84	61	237
**Longnosed Gar, Lepisosteus osseus	798	93	86	54	0	864	612	2507
**Shortnosed Gar, Lepisosteus platostomus	2304	639	548	490	42	2461	348	6832
Spotted Gar, Lepisosteus oculatus	3	0	11	36	72	84	1282	1488
*Sauger, Stizostedion canadense	96	57	18	23	0	45	0	239
American Eel, Anguilla rostrata	0	0	2	1	2	4	11	20
*Chain Pickerel, Esox niger	0	0	0	0	0	1	0	1
Atlantic Needlefish, Strongylura marina	0	0	0	0	0	0	0	0
*Northern Pike, Esox lucius	0	7	0	0	0	0	0	7
*Gaff Topsail Catfish, Bagre marinus	0	0	0	0	2	0	0	2
Ladyfish, Elops saurus	0	0	0	0	11	0	0	11
*Crevalle Jack, Caranx hippos	0	0	0	0	1	0	0	1
*Silver Sea Trout, Cynoscion nothus	0	0	0	0	0	0	0	0
Horse Eye Jack, Caranx latus	0	0	0	0	0	0	0	0
*Spotted Bass, Micropterus punctulatus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-4 Continued Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1966.

Non-predacious fish								
**Bigmouth Buffalo, Ictiobus cyprinellus	624	708	436	640	613	587	77	3685
**Black Buffalo, Ictiobus niger	278	205	189	268	477	100	86	1603
**Smallmouth Buffalo, Ictiobus bubalus	705	329	1193	641	1404	416	1433	6121
*Bluegill, Leopmis macrochirus	5	4	0	7	1	3	1	21
**Brown Bullhead, Ictalurus nebulosus	0	0	0	1	3	7	1	12
**Black Bullhead, Ictalurus melas	2	17	0	3	5	6	7	40
**Yellow Bullhead, Ictalurus natalis	0	0	0	0	1	3	11	15
**Carp, Cyprinus carpio	1287	1240	468	1620	977	453	400	6445
**Quillback Carpsucker, Carpiodes cyprinus	10	24	1	0	0	0	1	36
**River Carpsucker, Carpiodes carpio	1418	755	411	266	5	321	16	3192
Sea Catfish, Galeichthys felis	0	0	0	0	20	0	0	20
Pirate Perch, Aphredoderus sayanus	0	0	0	0	0	0	0	0
**Fresh-Water Drum, Aplodinotus grunniens	191	136	304	175	119	250	113	1288
Goldeye, Hiodon alosoides	50	16	16	15	0	226	0	323
Skipjack Herring, Alosa chrysochloris	114	87	244	115	261	273	29	1123
Mooneye, Hiodon tergisus	0	2	0	0	0	0	0	2
**Silver Mullet, Mugil curema	0	0	0	0	0	1	0	1
**Striped Mullet, Mugil cephalus	0	0	2	21	62	85	1364	1534
**Paddlefish, Polyodon spathula	39	36	64	32	1	35	25	232
Gizzard Shad, Dorosoma cepedianum	566	691	538	767	663	886	494	4605
Threadfin Shad, Dorosoma petenense	1	4	10	11	46	16	2	90
Golden Shiner, Notemigonus crysoleucas	0	0	0	0	0	0	0	0
**Shovelnose Sturgeon, Scaphirhynchus platorynchus	74	2	0	0	0	1	0	77
*Longear Sunfish, Lepomis megalotis	2	1	0	0	0	1	0	4
*Redear Sunfish, Lepomis microlophus	0	0	0	0	0	0	3	3
*Warmouth, Chaenobryttus gulosus	0	0	0	1	0	0	2	3
**Spotted Sucker, Minytrema melanops	0	3	3	11	0	1	1	19
Hogchoker, Trinectes maculatus	0	0	0	0	0	0	0	0
**Blue Sucker, Cycleptus elongatus	0	6	36	0	0	0	0	42
**Chub Sucker, Erimyzon sp	0	0	0	0	0	1	1	2
Flathead Chub, Hybopsis gracilis	0	0	0	0	0	0	0	0
Silver Chub, Hybopsis storeriana	0	0	0	0	0	0	0	0
**Golden Redhorse, Moxostoma erythrurum	0	0	1	0	0	0	0	1
**Menhaden, Brevoortia patronus	0	0	0	0	87	0	1	88
**Croaker, Micropogon undulatus	0	0	0	0	0	0	0	0
**Spot, Leiostomus xanthurus	0	0	0	0	0	0	0	0
Blunt Nose Stingray, Dasyatis sayi	0	0	0	0	11	0	0	11
Flier, Centrarchus necropterus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-4 Continued Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1966.

	Sampling Stations							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
TOTAL	9348	5682	5315	6136	5531	8421	6795	47228
Game Fish	337	255	232	319	133	521	72	1869
Non-Game Fish	9011	5427	5083	5817	5398	7900	6723	45359
Commercial Fish	8252	4604	4258	4770	4262	6289	4740	37175
Non-Commercial Fish	1096	1078	1057	1366	1269	2132	2055	10053

Table I-4a Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1967.

	Sampling Stations							
Common and scientific names	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
Predacious fish								
*Largemouth Bass, Micropterus salmoides	0	7	13	7	9	22	8	66
*White Bass, Roccus chrysops	149	26	116	141	41	154	62	689
*Yellow Bass, Roccus mississippiensis	12	1	1	3	25	20	7	69
Bowfin, Amia calva	14	15	0	43	53	37	40	202
**Blue Catfish, Ictalurus furcatus	51	143	182	540	257	194	47	1414
**Channel Catfish, Ictalurus punctatus	97	88	84	76	249	36	51	681
**Flathead Catfish, Pylodictis olivaris	97	116	259	147	0	76	0	695
*Black Crappie, Pomoxis nigromaculatus	2	6	51	12	28	23	15	137
*White Crappie, Pomoxis annularis	30	53	170	53	21	104	16	447
**Flounder, Paralichthys sp	0	0	0	0	54	0	17	71
**Alligator Gar, Lepisosteus spatula	0	99	0	0	62	60	77	298
**Longnosed Gar, Lepisosteus osseus	260	119	100	25	4	492	273	1273
**Shortnosed Gar, Lepisosteus platostomus	1172	282	363	261	46	849	299	3272
Spotted Gar, Lepisosteus oculatus	0	0	10	19	15	43	1157	1244
*Sauger, Stizostedion canadense	125	162	43	12	2	42	1	387
American Eel, Anguilla rostrata	4	0	0	0	0	0	2	6
*Chain Pickerel, Esox niger	0	0	0	1	0	1	0	2
Atlantic Needlefish, Strongylura marina	0	0	0	0	0	0	0	0
*Northern Pike, Esox lucius	1	0	0	0	0	0	0	1
*Gaff Topsail Catfish, Bagre marinus	0	0	0	0	0	0	0	0
Ladyfish, Elops saurus	0	0	0	0	2	0	0	2
*Crevalle Jack, Caranx hippos	0	0	0	0	0	0	0	0
*Silver Sea Trout, Cynoscion nothus	0	0	0	0	0	0	0	0
Horse Eye Jack, Caranx latus	0	0	0	0	0	0	0	0
*Spotted Bass, Micropterus punctulatus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-4a Continued Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1967.

	Sampling Stations							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
TOTAL	6164	5765	4925	4041	7519	5751	4979	39144
Game Fish	321	261	400	231	129	366	118	1826
Non-Game Fish	5843	5504	4525	3810	7390	5385	4861	37318
Commercial Fish	5352	4984	3213	2933	5504	3722	3164	28872
Non-Commercial Fish	812	781	1712	1108	2015	2029	1815	10272

Table I-4b Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1968.

	Sampling Stations							
Common and scientific names	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
Predacious fish								
*Largemouth Bass, Micropterus salmoides	13	3	3	11	6	17	11	64
*White Bass, Roccus chrysops	104	18	125	52	14	65	25	403
*Yellow Bass, Roccus mississippiensis	12	1	2	4	4	1	9	33
Bowfin, Amia calva	5	0	47	26	18	40	135	271
**Blue Catfish, Ictalurus furcatus	104	81	170	278	320	228	88	1269
**Channel Catfish, Ictalurus punctatus	151	65	49	54	215	55	28	617
**Flathead Catfish, Pylodictis olivaris	56	125	275	136	2	21	19	634
*Black Crappie, Pomoxis nigromaculatus	1	4	37	16	2	24	25	109
*White Crappie, Pomoxis annularis	25	35	220	98	18	93	7	496
**Flounder, Paralichthys sp	0	0	0	0	29	0	7	36
**Alligator Gar, Lepisosteus spatula	0	0	0	0	11	61	99	171
**Longnosed Gar, Lepisosteus osseus	167	91	60	4	2	190	210	724
**Shortnosed Gar, Lepisosteus platostomus	1778	283	392	219	6	508	166	3352
Spotted Gar, Lepisosteus oculatus	0	0	4	27	1	25	571	628
*Sauger, Stizostedion canadense	137	149	22	6	2	15	1	332
American Eel, Anguilla rostrata	3	0	0	0	0	0	2	5
*Chain Pickerel, Esox niger	0	0	0	0	0	0	0	0
Atlantic Needlefish, Strongylura marina	0	0	0	0	0	0	0	0
*Northern Pike, Esox lucius	0	0	0	0	0	0	0	0
*Gaff Topsail Catfish, Bagre marinus	0	0	0	0	0	0	0	0
Ladyfish, Elops saurus	0	0	0	0	0	0	0	0
*Crevalle Jack, Caranx hippos	0	0	0	0	0	0	0	0
*Silver Sea Trout, Cynoscion nothus	0	0	0	0	0	0	0	0
Horse Eye Jack, Caranx latus	0	0	0	0	0	0	0	0
*Spotted Bass, Micropterus punctulatus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-4b Continued Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1968.

Non-predacious fish								
**Bigmouth Buffalo, Ictiobus cyprinellus	183	306	354	232	1265	357	98	2795
**Black Buffalo, Ictiobus niger	232	90	6	125	22	56	73	604
**Smallmouth Buffalo, Ictiobus bubalus	247	211	493	191	1077	642	682	3543
*Bluegill, Leopmis macrochirus	2	6	5	2	0	3	1	19
**Brown Bullhead, Ictalurus nebulosus	0	0	4	0	0	0	2	6
**Black Bullhead, Ictalurus melas	3	0	0	0	0	0	0	3
**Yellow Bullhead, Ictalurus natalis	0	0	2	0	0	2	1	5
**Carp, Cyprinus carpio	834	472	848	442	505	383	414	3898
**Quillback Carpsucker, Carpiodes cyprinus	36	11	0	0	0	0	0	47
**River Carpsucker, Carpiodes carpio	1670	2043	711	216	13	547	5	5205
Sea Catfish, Galeichthys felis	0	0	0	0	1	0	0	1
Pirate Perch, Aphredoderus sayanus	0	0	0	0	0	0	0	0
**Fresh-Water Drum, Aplodinotus grunniens	199	208	73	129	150	163	102	1024
Goldeye, Hiodon alosoides	93	23	19	6	0	10	0	151
Skipjack Herring, Alosa chrysochloris	48	127	296	82	279	294	4	1130
Mooneye, Hiodon tergisus	1	0	0	0	0	0	0	1
**Silver Mullet, Mugil curema	0	0	0	0	2	11	0	13
**Striped Mullet, Mugil cephalus	0	0	3	8	144	155	618	928
**Paddlefish, Polyodon spathula	59	102	22	208	0	122	11	524
Gizzard Shad, Dorosoma cepedianum	412	361	523	380	536	459	181	2852
Threadfin Shad, Dorosoma petenense	0	7	31	36	4	28	1	107
Golden Shiner, Notemigonus crysoleucas	0	1	0	0	0	0	0	1
**Shovelnose Sturgeon, Scaphirhynchus platorynchus	2	8	0	0	0	0	0	10
*Longear Sunfish, Lepomis megalotis	0	1	0	0	0	0	0	1
*Redear Sunfish, Lepomis microlophus	0	0	0	0	0	1	0	1
*Warmouth, Chaenobryttus guiosus	0	0	0	0	0	2	1	3
**Spotted Sucker, Minytrema melanops	0	3	0	0	2	2	0	7
Hogchoker, Trinectes maculatus	0	0	0	0	0	0	0	0
**Blue Sucker, Cycleptus elongatus	0	0	0	0	0	0	0	0
**Chub Sucker, Erimyzon sp	3	0	0	0	0	0	0	3
Flathead Chub, Hybopsis gracilis	0	0	0	41	0	0	4	45
Silver Chub, Hybopsis storeriana	0	1	0	0	0	0	0	1
**Golden Redhorse, Moxostoma erythrurum	1	0	0	0	0	0	0	1
**Menhaden, Brevoortia patronus	0	0	0	0	2	0	0	2
**Croaker Micropogon undulatus	0	0	0	0	0	0	0	0
**Spot, Leiostomus xanthurus	0	0	0	0	0	0	0	0
Blunt Nose Stingray, Dasyatis sayi	0	0	0	0	1	0	0	1
Flier, Centrarchus necropterus	0	0	0	0	0	0	0	0

*Game Fish
**Commercial Fish

Table I-4b Continued Total pounds of fish caught by sampling gear fished in Mississippi and Atchafalaya Rivers, during 1968.

	Sampling Stations							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	TOTAL
TOTAL	6581	4836	4796	3029	4653	4580	3601	32076
Game Fish	294	217	414	189	46	221	80	1461
Non-Game Fish	6287	4619	4382	2840	4607	4359	3521	30615
Commercial Fish	5725	4099	3462	2242	3767	3503	2623	25421
Non-Commercial Fish	856	737	1334	787	886	1077	978	6655

Table I-5 Number of fish caught per net day from Mississippi and Atchafalaya Rivers during 1966

Sampling Period	Sampling Station							Average Mean
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
01								
Gill net	29.100	16.000	4.800	8.500	12.667	27.000	9.400	15.352
Trammel net	29.100	9.500	6.333	7.042	20.666	13.100	14.292	14.290
Hoop net	1.079	.875	1.531	1.775	1.333	3.081	.575	1.464
Mean	19.760	8.792	4.221	5.772	11.555	14.394	8.089	10.369
02								
Gill net	15.300	14.100	2.800	10.900	3.400	27.000	24.300	13.971
Trammel net	12.070	5.633	4.200	10.367	4.541	21.033	19.867	11.102
Hoop net	2.382	2.350	1.500	10.750	.250	5.875	.750	3.408
Mean	9.917	7.361	2.833	10.672	2.730	17.969	14.972	9.493
03								
Gill net	35.800	17.400	56.800	14.900	43.400	8.700	38.100	30.729
Trammel net	6.633	12.833	19.203	3.833	7.967	9.567	20.900	11.562
Hoop net	1.675	3.971	4.825	4.550	2.250	2.950	1.325	3.078
Mean	14.703	11.401	26.943	7.761	17.872	7.072	20.108	15.123
04								
Gill net	48.200	33.300	15.800	14.300	6.600	12.300	8.125	19.804
Trammel net	23.400	16.700	10.389	9.200	6.300	27.667	8.933	14.656
Hoop net	2.725	2.975	2.950	4.900	4.950	1.638	3.144	3.326
Mean	24.775	17.658	9.713	9.467	5.950	13.868	6.734	12.595
05								
Gill net	13.500	12.000	9.700	19.000	4.400	66.700	12.500	19.686
Trammel net	10.067	10.900	8.267	9.000	3.825	16.433	21.578	11.439
Hoop net	1.800	1.775	1.700	2.933	2.575	2.081	.825	1.956
Mean	8.456	8.225	6.556	10.311	3.600	28.405	11.634	11.027
06								
Gill net	7.400	23.800	5.625	47.300	30.000	28.200	17.600	22.846
Trammel net	18.267	13.733	7.519	16.567	11.400	16.667	19.933	14.869
Hoop net	.425	.700	.875	3.867	3.450	1.333	.975	1.661
Mean	8.697	12.744	4.673	22.578	14.950	15.400	12.836	13.125
07								
Gill net	22.200	23.700	22.100	21.900	85.200	31.000	22.300	32.629
Trammel net	13.300	12.700	11.593	17.533	14.267	15.748	12.633	13.968
Hoop net	.500	.625	.450	.575	5.127	.950	1.325	1.365
Mean	12.000	12.342	11.381	13.336	34.865	15.899	12.086	15.987
08								
Gill net	12.500	24.200	12.400	26.200	89.600	60.200	8.200	33.329
Trammel net	11.733	9.217	11.141	14.467	10.767	17.474	5.767	11.509
Hoop net	2.625	.900	2.314	2.819	1.258	1.010	.281	1.601
Mean	8.953	11.439	8.618	14.495	33.875	26.228	4.749	15.480
All Periods								
Gill net	23.000	20.563	16.253	20.375	34.408	32.638	17.566	23.543
Trammel net	15.571	11.402	9.831	11.001	9.967	17.211	15.488	12.924
Hoop net	1.651	1.771	2.018	4.021	2.649	2.365	1.150	2.232
Mean	13.407	11.245	9.367	11.799	15.675	17.405	11.401	12.900

Table I-5a Number of fish caught per net day from Mississippi and Atchafalaya Rivers during 1967

Sampling Period	Sampling Station							Average Mean
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
01								
Gill net	30.429	31.800	7.300	26.800	9.600	27.900	16.400	21.461
Trammel net	13.683	16.600	39.933	14.500	11.833	26.800	12.500	19.407
Hoop net	1.886	1.350	5.550	2.100	.950	1.500	.175	1.930
Mean	15.333	16.583	17.594	14.467	7.461	18.733	9.692	14.266
02								
Gill net	4.625	8.375	4.875	22.125	52.625	30.500	24.125	21.036
Trammel net	3.167	13.000	4.875	10.333	26.720	22.806	11.375	13.182
Hoop net	.067	.188	11.444	.604	1.875	8.146	.688	3.287
Mean	2.620	7.188	7.065	11.021	27.073	20.484	12.063	12.502
03								
Gill net	6.125	21.750	11.625	16.875	172.625	32.375	18.429	39.972
Trammel net	10.375	10.792	7.042	13.292	19.458	21.875	14.190	13.861
Hoop net	4.781	2.531	3.386	4.625	3.085	5.813	1.106	3.618
Mean	7.094	11.691	7.351	11.597	65.056	20.021	11.242	19.150
04								
Gill net	24.875	14.875	12.875	40.250	12.625	31.750	6.875	20.589
Trammel net	18.708	21.292	19.000	10.792	11.403	16.917	10.625	15.534
Hoop net	11.938	4.031	4.125	.813	4.875	3.063	1.531	4.339
Mean	18.507	13.399	12.000	17.285	9.634	17.243	6.344	13.487
05								
Gill net	28.750	11.500	10.500	22.250	17.375	11.125	34.000	19.357
Trammel net	18.458	18.472	9.500	6.708	7.250	17.375	15.250	13.288
Hoop net	2.958	1.969	2.531	.906	1.406	.938	2.000	1.815
Mean	16.722	10.647	7.510	9.955	8.677	9.813	17.083	11.487
06								
Gill net	29.500	23.250	21.750	21.375	37.875	6.750	49.333	27.119
Trammel net	11.125	9.292	12.792	5.417	9.583	8.917	21.194	11.189
Hoop net	.250	.719	1.375	.563	2.625	.656	.084	.896
Mean	13.625	11.087	11.972	9.118	16.694	5.441	23.537	13.068
07								
Gill net	18.000	29.750	43.875	79.375	43.375	10.375	59.250	40.571
Trammel net	8.333	10.125	13.667	13.542	15.375	13.375	21.250	13.667
Hoop net	.500	1.813	1.813	.438	1.219	.969	.438	1.027
Mean	8.944	13.896	19.785	31.118	19.990	8.240	26.979	18.422
08								
Gill net	15.000	11.000	13.625	34.875	22.125	33.500	32.125	23.179
Trammel net	10.875	8.583	7.333	9.472	8.833	16.458	19.708	11.609
Hoop net	1.844	.344	1.313	.750	1.219	1.167	.063	.957
Mean	9.240	6.642	7.424	15.032	10.726	17.042	17.299	11.915
All Periods								
Gill net	19.663	19.038	15.803	32.991	46.028	23.034	30.067	26.661
Trammel net	11.841	13.520	14.268	10.507	13.807	18.065	15.762	13.967
Hoop net	3.028	1.618	3.942	1.350	2.157	2.782	.761	2.234
Mean	11.511	11.392	11.338	14.949	20.664	14.627	15.530	14.287

Table I-5b Number of fish caught per net day from Mississippi and Atchafalaya Rivers during 1968

Sampling Period	Sampling Station							Average Mean
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
01								
Gill net	.875	7.000	12.000	12.500	25.375	6.500	3.250	9.643
Trammel net	1.833	2.875	11.833	2.375	9.250	3.083	5.167	5.202
Hoop net	.594	1.750	3.813	.031	4.969	2.531	.219	1.987
Mean	1.101	3.875	9.215	4.969	13.198	4.038	2.879	5.611
02								
Gill net	44.375	16.250	8.625	63.625	15.125	13.125	21.750	26.125
Trammel net	31.972	19.750	9.931	11.458	19.736	10.292	8.417	15.937
Hoop net	3.063	.625	7.000	3.656	2.219	1.438	.156	2.594
Mean	26.470	12.208	8.519	26.246	12.360	8.285	10.108	14.885
03								
Gill net	4.375	25.500	66.500	24.875	17.000	44.375	9.250	27.411
Trammel net	14.292	9.375	18.792	4.667	5.000	11.875	7.458	10.208
Hoop net	.729	3.750	.969	1.125	1.531	1.938	.344	1.484
Mean	6.465	12.875	28.754	10.222	7.844	19.396	5.684	13.034
04								
Gill net	17.750	13.375	3.625	6.250	12.875	20.500	4.875	11.321
Trammel net	16.833	17.042	8.667	3.125	5.917	6.167	4.917	8.953
Hoop net	4.750	1.469	.625	.281	1.938	1.469	.281	1.545
Mean	13.111	10.629	4.306	3.219	6.910	9.379	3.358	7.273
05								
Gill net	19.125	8.875	14.125	19.125	9.625	31.875	15.125	16.839
Trammel net	16.000	10.667	8.917	7.583	7.488	14.083	4.250	9.855
Hoop net	2.188	.844	.844	.250	3.406	1.094	.625	1.322
Mean	12.438	6.795	7.962	8.986	6.840	15.684	6.667	9.339
06								
Gill net	37.125	12.125	40.750	14.000	26.250	35.500	50.625	30.911
Trammel net	16.819	17.167	15.653	9.667	9.000	21.625	13.917	14.835
Hoop net	.875	.719	3.844	.531	.375	.594	.125	1.009
Mean	18.273	10.004	20.082	8.066	11.875	19.240	21.556	15.585
07								
Gill net	13.125	37.750	21.625	30.625	31.500	48.125	12.625	27.911
Trammel net	14.917	12.208	12.111	8.917	6.292	31.708	17.333	14.784
Hoop net	1.063	.969	1.281	.719	.438	.375	.313	.737
Mean	9.702	16.976	11.672	13.420	12.743	26.736	10.090	14.477
08								
Gill net	34.625	27.750	22.125	35.125	6.250	14.375	10.250	21.500
Trammel net	12.417	9.250	12.000	6.417	5.125	17.375	5.375	9.708
Hoop net	3.438	.781	3.844	.750	1.094	.844	.281	1.576
Mean	16.827	12.594	12.656	14.097	4.156	10.865	5.302	10.928
All Periods								
Gill net	21.422	18.578	23.672	25.766	18.000	26.797	15.969	21.458
Trammel net	15.635	12.292	12.238	6.776	8.476	14.526	8.354	11.185
Hoop net	2.088	1.363	2.778	.918	1.996	1.285	.293	1.569
Mean	13.048	10.744	12.896	11.153	9.491	14.203	8.205	11.392

Table I-6 Pounds of fish caught per net day from Mississippi and Atchafalaya Rivers during 1966

Sampling Period	Sampling Station							Average Mean
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
01								
Gill net	32.780	5.850	3.330	7.990	5.283	17.070	5.560	11.123
Trammel net	63.087	18.033	10.157	12.283	16.161	15.413	19.426	22.080
Hoop net	1.677	.213	2.010	1.605	.800	2.056	.508	1.267
Mean	32.515	8.032	5.166	7.293	7.415	11.513	8.498	11.490
02								
Gill net	18.130	6.090	2.930	9.140	1.960	21.300	17.070	10.946
Trammel net	42.153	15.097	11.553	23.250	11.876	29.786	25.413	22.733
Hoop net	2.287	5.483	4.278	13.413	.279	4.625	.630	4.428
Mean	20.857	8.890	6.254	15.268	4.705	18.570	14.371	12.702
03								
Gill net	26.380	9.420	25.210	7.250	10.230	9.800	35.030	17.617
Trammel net	21.650	32.077	31.619	8.410	15.117	24.123	40.910	24.844
Hoop net	6.041	10.641	7.709	5.930	1.883	3.455	1.730	5.341
Mean	18.024	17.379	21.513	7.197	9.077	12.459	25.890	15.934
04								
Gill net	31.300	21.130	15.030	4.660	4.960	12.660	9.550	14.184
Trammel net	34.163	18.797	24.033	17.930	16.827	45.733	17.527	25.001
Hoop net	5.058	5.113	3.948	6.533	7.545	1.763	3.925	4.841
Mean	23.507	15.013	14.337	9.708	9.777	20.052	10.334	14.675
05								
Gill net	12.070	12.520	7.160	8.200	1.840	68.660	20.133	18.655
Trammel net	12.687	15.950	13.550	11.163	11.477	21.737	28.669	16.462
Hoop net	5.003	6.058	3.085	2.917	3.525	2.165	1.010	3.395
Mean	9.920	11.509	7.932	7.427	5.614	30.854	16.604	12.837
06								
Gill net	7.130	15.080	4.013	20.740	10.040	22.090	22.660	14.536
Trammel net	19.037	13.897	11.213	17.603	18.460	29.133	21.703	18.721
Hoop net	.693	1.415	1.528	5.623	2.945	2.198	1.703	2.301
Mean	8.953	10.131	5.585	14.655	10.482	17.807	15.355	11.853
07								
Gill net	17.520	11.070	13.230	12.090	17.020	14.680	20.910	15.217
Trammel net	15.037	11.383	11.932	20.210	20.723	19.773	18.497	16.794
Hoop net	1.458	1.410	.670	.845	8.998	1.028	1.508	2.274
Mean	11.338	7.954	8.611	11.048	15.580	11.827	13.638	11.428
08								
Gill net	9.190	13.680	10.820	14.680	27.050	19.540	5.060	14.289
Trammel net	17.483	11.765	17.993	18.663	24.783	15.742	6.287	16.102
Hoop net	2.748	2.098	1.492	2.806	1.500	1.222	.327	1.742
Mean	9.807	9.181	10.102	12.050	17.778	12.168	3.891	10.711
All Periods								
Gill net	19.313	11.855	10.215	10.594	9.798	23.225	16.997	14.571
Trammel net	28.162	17.125	16.506	16.189	16.928	25.180	22.304	20.342
Hoop net	3.121	4.054	3.090	4.959	3.434	2.314	1.418	3.199
Mean	16.865	11.011	9.937	10.581	10.053	16.906	13.573	12.704

Table I-6a Pounds of fish caught per net day from Mississippi and Atchafalaya Rivers during 1967

Sampling Period	Sampling Station Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Average Mean
01								
Gill net	32.914	21.710	8.060	9.680	5.360	11.850	10.050	14.232
Trammel net	38.710	26.160	26.233	18.443	21.907	18.033	9.870	22.765
Hoop net	1.832	2.055	4.223	1.753	1.423	1.228	.098	1.802
Mean	24.485	16.642	12.839	9.959	9.563	10.370	6.673	12.933
02								
Gill net	1.613	4.288	5.950	12.688	32.050	13.538	26.563	13.813
Trammel net	5.467	23.513	9.992	12.975	31.182	22.556	21.654	18.191
Hoop net	.169	.613	12.042	1.316	1.633	3.880	.716	2.910
Mean	2.416	9.471	9.328	8.993	21.622	13.325	16.311	11.638
03								
Gill net	6.575	11.863	8.913	6.513	34.563	25.300	15.700	15.632
Trammel net	20.213	20.563	12.708	16.488	49.425	36.571	21.324	25.327
Hoop net	7.366	8.119	4.762	4.894	7.287	7.538	1.570	5.934
Mean	11.385	13.515	8.794	9.298	30.425	23.136	12.865	15.631
04								
Gill net	19.638	12.638	7.325	16.325	9.000	26.863	12.025	14.831
Trammel net	29.075	40.908	23.846	15.863	33.199	26.329	16.854	26.582
Hoop net	11.203	7.397	5.775	1.357	6.385	2.891	1.238	5.178
Mean	19.972	20.314	12.315	11.182	16.195	18.694	10.039	15.530
05								
Gill net	23.563	5.538	6.575	10.213	9.875	9.775	35.788	14.475
Trammel net	43.754	24.129	9.367	12.104	13.696	18.208	25.104	20.909
Hoop net	4.418	3.888	3.438	1.366	2.944	.691	1.366	2.587
Mean	23.912	11.185	6.460	7.894	8.838	9.558	20.753	12.657
06								
Gill net	17.338	16.125	8.775	15.625	21.975	2.550	31.800	16.313
Trammel net	19.613	14.534	10.600	11.117	16.950	17.088	29.186	17.013
Hoop net	.859	2.185	1.525	.397	2.310	.707	.150	1.162
Mean	12.603	10.948	6.967	9.046	13.745	6.782	20.379	11.496
07								
Gill net	6.513	9.338	21.325	18.850	17.263	8.188	27.025	15.500
Trammel net	11.163	11.013	19.854	14.171	45.329	14.442	23.421	19.913
Hoop net	.684	2.116	2.850	.863	2.341	1.047	.147	1.435
Mean	6.120	7.489	14.676	11.295	21.644	7.892	16.864	12.283
08								
Gill net	6.350	6.650	7.413	12.325	9.038	15.813	13.313	10.129
Trammel net	17.609	18.733	12.725	11.036	22.242	18.446	14.463	16.465
Hoop net	1.603	.669	4.244	1.933	1.260	1.996	.110	1.688
Mean	8.521	8.684	8.127	8.431	10.847	12.085	9.295	9.427
All Periods								
Gill net	14.313	11.019	9.292	12.777	17.391	14.235	21.533	14.366
Trammel net	23.201	22.444	15.666	14.025	29.241	21.459	20.235	20.896
Hoop net	3.517	3.380	4.857	1.735	3.198	2.497	.674	2.837
Mean	13.677	12.281	9.938	9.512	16.610	12.730	14.147	12.699

Table I-6b Pounds of fish caught per net day from Mississippi and Atchafalaya Rivers during 1968

	Sampling Station							
Sampling Period	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Average Mean
01								
Gill net	.525	4.075	4.413	3.488	23.600	2.438	2.175	5.816
Trammel net	4.092	5.242	16.225	3.067	18.008	4.354	11.038	8.861
Hoop net	.988	.700	2.810	.025	6.341	2.385	.103	1.907
Mean	1.868	3.339	7.816	2.193	15.983	3.059	4.439	5.528
02								
Gill net	20.050	13.100	6.500	15.638	4.200	5.388	14.625	11.357
Trammel net	58.397	31.692	21.161	16.550	48.064	15.554	17.267	29.812
Hoop net	3.269	.794	6.566	3.357	2.241	1.935	.385	2.649
Mean	27.239	15.195	11.409	11.848	18.168	7.626	10.759	14.606
03								
Gill net	7.125	22.075	25.500	6.575	10.175	26.563	4.100	14.588
Trammel net	27.950	19.255	31.408	9.113	18.300	23.463	15.792	20.754
Hoop net	.908	5.429	1.188	1.185	1.244	4.432	.781	2.167
Mean	11.994	15.586	19.365	5.624	9.906	18.153	6.891	12.503
04								
Gill net	17.738	10.163	5.113	2.413	3.375	8.325	2.975	7.157
Trammel net	31.742	32.413	13.463	7.021	19.175	9.521	10.363	17.671
Hoop net	7.975	4.269	1.360	.478	7.900	2.332	.575	3.556
Mean	19.152	15.615	6.645	3.304	10.150	6.726	4.638	9.461
05								
Gill net	19.875	5.738	10.475	14.488	3.338	19.163	15.613	12.670
Trammel net	26.921	11.213	11.650	12.250	12.621	19.146	12.121	15.132
Hoop net	3.475	.713	1.407	.497	3.422	1.960	1.047	1.789
Mean	16.757	5.888	7.844	9.078	6.460	13.423	9.594	9.863
06								
Gill net	18.063	12.475	11.875	11.014	17.213	16.188	33.925	17.250
Trammel net	23.740	23.800	21.353	19.521	12.200	20.113	20.167	20.128
Hoop net	1.191	1.747	3.916	.697	.572	.541	.278	1.277
Mean	14.331	12.674	12.381	10.411	9.995	12.281	18.123	12.885
07								
Gill net	6.025	12.888	9.138	13.000	9.075	17.963	13.338	11.632
Trammel net	17.904	16.188	12.674	12.279	12.588	24.992	19.088	16.530
Hoop net	1.922	2.525	1.935	.775	.241	.638	.307	1.192
Mean	8.617	10.534	7.916	8.685	7.301	14.531	10.911	9.785
08								
Gill net	15.488	7.813	14.563	10.838	2.488	7.488	6.163	9.263
Trammel net	22.638	16.271	21.367	11.009	12.559	19.559	8.421	15.975
Hoop net	3.682	1.447	1.600	.900	1.485	1.051	.554	1.531
Mean	13.936	8.510	12.510	7.582	5.511	9.366	5.046	8.923
All Periods								
Gill net	13.111	11.041	10.947	9.682	9.183	12.940	11.614	11.217
Trammel net	26.673	19.509	18.663	11.351	19.189	17.088	14.282	18.108
Hoop net	2.926	2.203	2.598	.989	2.931	1.909	.504	2.009
Mean	14.237	10.918	10.736	7.341	10.434	10.646	8.800	10.444

Table I-7 Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1966.

Species of fish	Sampling station							Total for year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
White bass								
Gill net	.308	.095	.708	.265	.151	2.159	.067	.536
Trammel net	.133	.056	.373	.244	.048	.250	.081	.169
Hoop net	.053	.003	.035	.072	.005	.028	.000	.028
Mean	.165	.051	.372	.194	.068	.812	.049	.244
Yellow bass								
Gill net	.203	.010	.010	.016	.059	.151	.086	.076
Trammel net	.073	.002	.000	.006	.124	.046	.030	.040
Hoop net	.000	.000	.000	.000	.000	.031	.003	.005
Mean	.092	.004	.003	.007	.061	.076	.040	.040
Blue catfish								
Gill net	.524	.219	.784	1.391	.570	.677	.210	.625
Trammel net	.791	.391	.640	.401	.090	1.171	.077	.509
Hoop net	.027	.075	.045	.237	.045	.108	.044	.083
Mean	.447	.228	.490	.676	.235	.652	.110	.405
Channel catfish								
Gill net	.674	.706	.160	.823	.633	.584	.331	.559
Trammel net	.291	.283	.096	.150	.153	.051	.144	.167
Hoop net	.106	.299	.053	.143	.363	.040	.131	.162
Mean	.357	.429	.103	.372	.383	.225	.202	.296
Black crappie								
Gill net	.019	.154	.033	.066	.155	.204	.032	.095
Trammel net	.036	.037	.019	.179	.100	.123	.043	.077
Hoop net	.006	.002	.000	.063	.033	.024	.004	.019
Mean	.020	.064	.017	.103	.096	.117	.026	.063
White crappie								
Gill net	.278	.635	.143	.090	.044	.493	.020	.243
Trammel net	.331	.512	.192	.240	.031	.433	.024	.252
Hoop net	.020	.000	.010	.109	.008	.045	.009	.029
Mean	.210	.382	.115	.146	.028	.324	.018	.175
Longnose gar								
Gill net	1.550	.398	.138	.218	.010	1.855	2.501	.953
Trammel net	2.749	.195	.395	.062	.000	2.828	1.814	1.149
Hoop net	.002	.059	.007	.074	.000	.144	.065	.050
Mean	1.434	.217	.180	.118	.003	1.609	1.460	.717
Shortnose gar								
Gill net	9.504	1.858	2.171	2.071	.218	7.248	1.826	3.557
Trammel net	6.342	2.233	1.914	1.179	.090	7.718	.975	2.922
Hoop net	.077	.030	.059	.148	.015	.172	.000	.072
Mean	5.308	1.374	1.381	1.133	.108	5.046	.934	2.183

Table I-7 Continued Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1966.

Species of fish	Sampling station							Total for year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
Flathead catfish								
Gill net	.038	.074	.267	.050	.000	.134	.034	.085
Trammel net	.173	.137	.903	.361	.030	.548	.031	.312
Hoop net	.274	.340	.164	.258	.014	.156	.050	.179
Mean	.162	.184	.445	.223	.015	.279	.038	.192
Spotted gar								
Gill net	.020	.000	.080	.164	.084	.339	5.875	.937
Trammel net	.006	.000	.020	.085	.285	.233	3.856	.641
Hoop net	.000	.000	.000	.011	.000	.008	.016	.005
Mean	.009	.000	.033	.087	.123	.193	3.249	.528
Sauger								
Gill net	.274	.250	.091	.066	.000	.249	.004	.133
Trammel net	.260	.176	.040	.077	.000	.107	.000	.094
Hoop net	.061	.014	.006	.000	.000	.002	.000	.012
Mean	.198	.147	.046	.048	.000	.119	.001	.080
Smallmouth buffalo								
Gill net	.144	.153	.179	.295	.298	.468	.759	.328
Trammel net	2.306	1.049	3.995	1.977	4.718	1.324	4.980	2.907
Hoop net	.389	.522	.806	.493	1.001	.243	.637	.584
Mean	.946	.575	1.660	.922	2.006	.678	2.125	1.273
Carp								
Gill net	.221	.406	.241	1.020	.486	.408	.140	.417
Trammel net	3.946	3.725	1.634	4.535	3.119	1.641	1.608	2.887
Hoop net	1.017	1.280	.316	1.451	.850	.127	.025	.724
Mean	1.728	1.804	.730	2.335	1.485	.725	.591	1.343
River carpsucker								
Gill net	1.290	1.510	.409	.429	.020	1.129	.054	.692
Trammel net	5.078	3.026	1.443	.785	.014	.760	.036	1.592
Hoop net	.318	.223	.205	.153	.001	.185	.011	.157
Mean	2.229	1.586	.686	.456	.012	.691	.034	.813
Freshwater drum								
Gill net	.565	.244	.707	.296	.233	.055	.059	.308
Trammel net	.403	.340	.735	.340	.205	.574	.131	.390
Hoop net	.187	.193	.273	.250	.168	.346	.270	.241
Mean	.385	.259	.572	.295	.202	.325	.153	.313
Goldeye								
Gill net	.374	.148	.084	.051	.003	.904	.001	.224
Trammel net	.075	.025	.034	.036	.000	.629	.000	.114
Hoop net	.014	.022	.005	.010	.000	.022	.000	.010
Mean	.154	.065	.041	.032	.001	.518	.000	.116

Table I-7 Continued Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1966.

Species of fish	Sampling station Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Total for year
Skipjack herring								
Gill net	.513	.946	.949	.823	1.365	1.221	.172	.856
Trammel net	.276	.062	.740	.201	.621	.729	.065	.385
Hoop net	.025	.011	.012	.004	.017	.030	.000	.014
Mean	.271	.340	.567	.343	.668	.660	.079	.418
Striped mullet								
Gill net	.000	.000	.000	.094	.405	.461	2.469	.490
Trammel net	.000	.000	.010	.050	.101	.192	5.090	.778
Hoop net	.000	.000	.000	.006	.019	.008	.023	.008
Mean	.000	.000	.003	.050	.175	.220	2.527	.425
Gizzard shad								
Gill net	2.484	3.664	2.855	1.735	3.112	3.448	1.757	2.722
Trammel net	1.436	1.641	1.173	1.956	2.101	2.266	1.618	1.742
Hoop net	.096	.123	.225	.537	.144	.246	.035	.201
Mean	1.339	1.809	1.418	1.409	1.786	1.987	1.137	1.555
Threadfin shad								
Gill net	.021	.051	.118	.145	.546	.208	.024	.159
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.000	.002	.000	.009	.000	.000	.002
Mean	.007	.017	.040	.048	.185	.069	.008	.053
Golden shiner								
Gill net	.000	.001	.001	.000	.000	.000	.008	.001
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.000	.000	.000	.000	.003	.000
Shovelnose Sturgeon								
Gill net	.160	.000	.000	.000	.000	.000	.000	.023
Trammel net	.248	.010	.002	.000	.000	.005	.000	.038
Hoop net	.008	.000	.000	.000	.000	.000	.000	.001
Mean	.139	.003	.001	.000	.000	.002	.000	.021
Largescale menhaden								
Gill net	.000	.000	.000	.000	.728	.003	.014	.106
Trammel net	.000	.000	.000	.000	.123	.000	.000	.018
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.000	.000	.284	.001	.005	.041

Table I-7a Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1967.

Species of fish	Sampling station							Total for year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
White bass								
Gill net	.451	.219	.383	.504	.169	.654	.306	.384
Trammel net	.454	.040	.352	.474	.121	.535	.237	.316
Hoop net	.112	.012	.066	.015	.018	.008	.001	.033
Mean	.339	.090	.267	.331	.103	.399	.181	.244
Yellow bass								
Gill net	.137	.011	.017	.049	.102	.137	.086	.077
Trammel net	.022	.003	.004	.001	.096	.055	.008	.027
Hoop net	.000	.000	.000	.000	.002	.004	.000	.001
Mean	.053	.005	.007	.017	.067	.065	.031	.035
Blue catfish								
Gill net	.192	.384	.596	2.012	1.876	.618	.233	.844
Trammel net	.106	.531	.747	2.062	.598	.699	.132	.696
Hoop net	.138	.040	.002	.022	.101	.074	.036	.059
Mean	.145	.318	.448	1.365	.858	.464	.134	.533
Channel catfish								
Gill net	.369	.309	.444	.542	1.180	.124	.376	.478
Trammel net	.127	.146	.234	.184	.405	.075	.130	.186
Hoop net	.172	.156	.046	.008	.380	.054	.027	.120
Mean	.223	.204	.241	.245	.655	.084	.178	.261
Black crappie								
Gill net	.031	.022	.231	.046	.025	.062	.033	.064
Trammel net	.002	.026	.157	.042	.085	.095	.037	.063
Hoop net	.000	.000	.020	.002	.043	.004	.024	.013
Mean	.011	.016	.136	.030	.051	.054	.031	.047
White crappie								
Gill net	.052	.114	.302	.290	.072	.303	.109	.177
Trammel net	.130	.237	.740	.146	.081	.410	.023	.252
Hoop net	.013	.000	.019	.015	.005	.015	.020	.012
Mean	.065	.117	.354	.150	.053	.243	.051	.148
Longnose gar								
Gill net	.588	.553	.582	.142	.010	1.444	1.328	.664
Trammel net	1.074	.279	.300	.084	.022	1.991	1.099	.693
Hoop net	.068	.243	.032	.000	.000	.047	.000	.056
Mean	.577	.358	.305	.075	.011	1.161	.809	.471
Shortnose gar								
Gill net	4.722	1.213	1.364	1.949	.270	3.157	1.517	2.027
Trammel net	4.410	.970	1.171	.653	.152	3.274	1.216	1.692
Hoop net	.252	.057	.220	.029	.000	.063	.000	.089
Mean	3.128	.747	.918	.877	.141	2.165	.911	1.270

Table I-7a Continued **Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1967.**

Species of fish	Sampling station: Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Total for year
Flathead catfish								
Gill net	.000	.010	.147	.024	.000	.000	.000	.026
Trammel net	.266	.351	.943	.656	.000	.355	.000	.367
Hoop net	.219	.182	.349	.064	.000	.034	.000	.121
Mean	.162	.181	.480	.248	.000	.130	.000	.172
Spotted gar								
Gill net	.000	.000	.074	.194	.074	.463	5.532	.905
Trammel net	.000	.000	.023	.035	.056	.050	4.476	.663
Hoop net	.000	.000	.000	.000	.000	.016	.034	.007
Mean	.000	.000	.032	.076	.043	.176	3.347	.525
Sauger								
Gill net	.382	.834	.234	.075	.025	.245	.003	.257
Trammel net	.526	.535	.129	.034	.006	.117	.005	.193
Hoop net	.025	.018	.009	.003	.000	.006	.000	.009
Mean	.311	.462	.124	.037	.010	.123	.003	.153
Smallmouth buffalo								
Gill net	.187	.114	.074	.146	.045	.332	2.919	.545
Trammel net	2.493	2.386	2.048	1.062	9.250	2.076	4.337	3.379
Hoop net	.262	.577	.504	.307	.800	.285	.147	.412
Mean	.981	1.026	.875	.505	3.365	.898	2.468	1.445
Carp								
Gill net	.042	.089	.450	.147	1.007	.152	.569	.351
Trammel net	2.639	1.648	1.046	1.735	3.494	.885	1.099	1.792
Hoop met	.318	.399	.443	.393	.435	.284	.000	.325
Mean	1.000	.712	.646	.758	1.645	.440	.556	.822
River carpsucker								
Gill net	4.180	3.406	1.352	.462	.072	.716	.055	1.463
Trammel net	6.954	9.361	2.903	.876	.094	1.688	.018	3.128
Hoop net	.732	.496	.548	.223	.004	.247	.020	.324
Mean	3.955	4.421	1.601	.520	.057	.884	.031	1.638
Freshwater drum								
Gill net	.105	.660	.219	.597	.286	.102	.141	.301
Trammel net	.411	.607	.459	.476	.309	.250	.085	.371
Hoop net	.631	.432	.369	.405	.163	.393	.290	.383
Mean	.382	.566	.349	.493	.253	.248	.172	.352
Goldeye								
Gill net	.345	.115	.053	.077	.000	.387	.001	.140
Trammel net	.108	.036	.008	.015	.005	.209	.043	.061
Hoop net	.035	.005	.009	.000	.000	.015	.000	.009
Mean	.163	.052	.023	.031	.002	.204	.015	.070

Table I-7a Continued Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1967.

Species of fish	Sampling station: Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Total for year
Skipjack herring								
Gill net	.269	.397	1.173	1.954	2.237	.799	.337	1.024
Trammel net	.148	.432	.281	.613	1.743	1.462	.035	.673
Hoop net	.152	.000	.050	.000	.025	.027	.000	.036
Mean	.190	.276	.501	.856	1.335	.763	.124	.578
Striped mullet								
Gill net	.000	.000	.061	.004	.864	.925	4.534	.913
Trammel net	.000	.000	.000	.023	.548	.625	4.526	.817
Hoop net	.000	.000	.000	.000	.010	.027	.017	.008
Mean	.000	.000	.020	.009	.474	.526	3.026	.579
Gizzard shad								
Gill net	2.074	2.053	1.181	2.420	7.597	3.065	2.722	3.016
Trammel net	.997	1.175	3.254	1.705	3.621	3.889	1.549	2.313
Hoop net	.213	.069	1.263	.091	.230	.543	.010	.346
Mean	1.095	1.099	1.899	1.405	3.816	2.499	1.427	1.891
Threadfin shad								
Gill net	.027	.088	.161	.462	.989	.287	.020	.291
Trammel net	.000	.000	.000	.001	.000	.001	.001	.000
Hoop net	.000	.000	.001	.000	.000	.000	.000	.000
Mean	.009	.029	.054	.154	.330	.096	.007	.097
Golden shiner								
Gill net	.000	.000	.006	.000	.000	.000	.000	.001
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.002	.000	.000	.000	.000	.000
Shovelnose Sturgeon								
Gill net	.004	.009	.000	.000	.000	.000	.000	.002
Trammel net	.005	.045	.009	.000	.000	.006	.000	.009
Hoop net	.007	.003	.000	.000	.000	.018	.000	.004
Mean	.005	.019	.003	.000	.000	.008	.000	.005
Largescale menhaden								
Gill net	.000	.000	.000	.000	.124	.000	.002	.018
Trammel net	.000	.000	.000	.000	.011	.000	.000	.002
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.000	.000	.045	.000	.001	.007

Table I-7b Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1968.

Species of fish	Sampling station							Total for year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
White bass								
Gill net	.277	.103	.536	.275	.097	.442	.158	.270
Trammel net	.343	.050	.409	.169	.042	.165	.076	.179
Hoop net	.084	.008	.058	.011	.000	.022	.002	.026
Mean	.235	.054	.334	.152	.046	.210	.079	.159
Yellow bass								
Gill net	.071	.005	.017	.033	.010	.011	.081	.033
Trammel net	.044	.005	.010	.008	.014	.002	.024	.015
Hoop net	.001	.000	.000	.002	.003	.001	.000	.001
Mean	.039	.003	.009	.014	.009	.005	.035	.016
Blue catfish								
Gill net	.664	.267	.708	1.506	1.489	.789	.428	.836
Trammel net	.322	.358	.660	.937	1.089	.890	.312	.653
Hoop net	.001	.009	.020	.012	.074	.028	.007	.022
Mean	.329	.211	.463	.818	.884	.569	.249	.503
Channel catfish								
Gill net	.549	.185	.407	.401	.994	.213	.206	.422
Trammel net	.583	.191	.116	.104	.526	.200	.078	.257
Hoop net	.039	.100	.006	.037	.240	.015	.001	.063
Mean	.390	.159	.176	.181	.587	.143	.095	.247
Black crappie								
Gill net	.000	.025	.124	.134	.000	.082	.014	.054
Trammel net	.000	.016	.150	.041	.011	.098	.118	.062
Hoop net	.005	.001	.004	.000	.000	.003	.006	.003
Mean	.002	.014	.093	.058	.004	.061	.046	.040
White crappie								
Gill net	.096	.092	.642	.281	.030	.310	.024	.211
Trammel net	.115	.167	.983	.413	.085	.383	.027	.310
Hoop net	.000	.005	.008	.007	.002	.002	.001	.004
Mean	.070	.088	.544	.234	.039	.232	.017	.175
Longnose gar								
Gill net	.367	.842	.658	.038	.036	1.486	.625	.579
Trammel net	.746	.307	.088	.009	.000	.486	.890	.361
Hoop net	.010	.006	.006	.000	.000	.007	.000	.004
Mean	.374	.385	.251	.016	.012	.660	.505	.315
Shortnose gar								
Gill net	5.335	2.239	2.294	1.121	.016	3.310	1.108	2.203
Trammel net	7.280	.704	1.163	.757	.028	1.526	.498	1.708
Hoop net	.184	.088	.130	.011	.000	.014	.000	.061
Mean	4.266	1.010	1.196	.630	.015	1.617	.535	1.324

Table I-7b Continued Pounds of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1968.

Species of fish	Sampling station							Total for year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
Flathead catfish								
Gill net	.131	.041	.080	.117	.000	.000	.000	.053
Trammel net	.165	.536	1.469	.668	.000	.042	.065	.421
Hoop net	.071	.078	.030	.002	.011	.053	.029	.039
Mean	.122	.218	.526	.262	.004	.032	.031	.171
Spotted gar								
Gill net	.000	.000	.077	.293	.006	.195	2.674	.464
Trammel net	.000	.000	.000	.053	.000	.069	2.083	.315
Hoop net	.000	.000	.000	.000	.004	.000	.000	.001
Mean	.000	.000	.026	.115	.003	.088	1.586	.260
Sauger								
Gill net	.655	.667	.083	.078	.034	.049	.005	.224
Trammel net	.410	.577	.084	.008	.000	.057	.006	.163
Hoop net	.066	.015	.010	.000	.000	.005	.000	.014
Mean	.377	.420	.059	.029	.011	.037	.004	.134
Smallmouth buffalo								
Gill net	.214	.069	.214	.138	.205	.264	1.507	.373
Trammel net	1.059	.841	2.390	.753	5.283	2.741	2.834	2.272
Hoop net	.135	.180	.116	.149	.546	.389	.163	.240
Mean	.469	.363	.907	.347	2.011	1.131	1.501	.961
Carp								
Gill net	.458	.222	.697	.199	.567	.150	.503	.399
Trammel net	4.013	2.079	3.731	2.057	1.824	1.623	1.992	2.474
Hoop net	.185	.307	.409	.140	.475	.243	.000	.251
Mean	1.552	.869	1.612	.799	.955	.672	.832	1.042
River carpsucker								
Gill net	.594	2.871	1.030	.435	.025	.860	.030	.835
Trammel net	6.289	8.764	2.612	.861	.050	2.410	.019	3.001
Hoop net	1.728	.799	.591	.095	.010	.116	.000	.477
Mean	2.870	4.145	1.411	.464	.028	1.129	.016	1.438
Freshwater drum								
Gill net	.507	.422	.214	.315	.249	.339	.236	.326
Trammel net	.739	.847	.240	.348	.321	.295	.197	.427
Hoop net	.120	.139	.060	.167	.293	.334	.193	.187
Mean	.455	.469	.171	.277	.288	.323	.209	.313
Goldeye								
Gill net	.952	.086	.120	.088	.000	.052	.002	.186
Trammel net	.096	.086	.041	.006	.000	.037	.000	.038
Hoop net	.055	.006	.017	.000	.000	.000	.000	.011
Mean	.368	.059	.059	.031	.000	.030	.001	.078

Table I-7b Continued Pounds of fish per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1968.

Species of fish	Sampling station							Total for year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
Skipjack herring								
Gill net	.147	.547	.724	.575	.746	1.596	.000	.619
Trammel net	.199	.463	1.255	.142	1.286	.985	.022	.622
Hoop net	.008	.031	.055	.072	.041	.011	.000	.031
Mean	.118	.347	.678	.263	.691	.864	.007	.424
Striped mullet								
Gill net	.000	.000	.000	.017	.988	.135	2.586	.532
Trammel net	.000	.000	.018	.039	.421	.749	2.352	.511
Hoop net	.000	.000	.000	.000	.003	.013	.004	.003
Mean	.000	.000	.006	.019	.471	.299	1.647	.349
Gizzard shad								
Gill net	1.822	2.013	1.705	2.165	3.174	1.741	1.308	1.990
Trammel net	1.556	1.234	1.411	.988	1.386	1.596	.494	1.238
Hoop net	.049	.047	.642	.214	.469	.163	.010	.228
Mean	1.142	1.098	1.253	1.122	1.676	1.167	.604	1.152
Threadfin shad								
Gill net	.011	.113	.491	.561	.075	.428	.017	.242
Trammel net	.000	.001	.001	.000	.000	.003	.000	.001
Hoop net	.000	.000	.002	.002	.000	.002	.000	.001
Mean	.004	.038	.165	.188	.025	.144	.006	.081
Golden shiner								
Gill net	.000	.002	.003	.000	.000	.000	.000	.001
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.004	.000	.000	.000	.000	.000	.001
Mean	.000	.002	.001	.000	.000	.000	.000	.000
Shovelnose Sturgeon								
Gill net	.011	.000	.000	.000	.003	.000	.000	.002
Trammel net	.009	.040	.002	.000	.002	.005	.000	.008
Hoop net	.000	.008	.000	.000	.000	.000	.000	.001
Mean	.007	.016	.001	.000	.002	.002	.000	.004
Largescale menhaden								
Gill net	.000	.000	.000	.000	.033	.000	.003	.005
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.000	.000	.011	.000	.001	.002

Table I-8 Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafaylaya Rivers during 1966

	Sampling Station							
Species of fish	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Total for Year
White Bass								
Gill net	.413	.413	.588	.375	.138	2.703	.178	.687
Trammel net	.129	.029	.289	.230	.039	.263	.118	.157
Hoop net	.065	.003	.030	.074	.013	.041	.000	.032
Mean	.202	.148	.302	.226	.063	1.002	.099	.292
Yellow bass								
Gill net	.863	.050	.025	.188	.138	.619	.508	.342
Trammel net	.158	.004	.000	.013	.251	.108	.075	.087
Hoop net	.000	.000	.000	.000	.000	.116	.009	.018
Mean	.340	.018	.008	.067	.130	.281	.197	.149
Blue catfish								
Gill net	.500	.425	1.797	3.288	2.017	1.497	.346	1.410
Trammel net	.301	.467	.794	.454	.096	1.016	.078	.458
Hoop net	.008	.095	.072	.527	.103	.244	.075	.161
Mean	.270	.329	.888	1.423	.739	.919	.166	.676
Channel catfish								
Gill net	.513	.850	.163	2.063	2.529	1.181	.605	1.129
Trammel net	.179	.208	.050	.113	.216	.042	.185	.142
Hoop net	.072	.219	.028	.165	.836	.144	.309	.253
Mean	.255	.426	.080	.780	1.194	.456	.366	.508
Black crappie								
Gill net	.038	.413	.063	.163	.263	.519	.058	.217
Trammel net	.075	.092	.033	.363	.167	.250	.096	.154
Hoop net	.009	.003	.000	.138	.063	.045	.016	.039
Mean	.041	.169	.032	.221	.164	.271	.057	.136
White crappie								
Gill net	.675	1.475	.338	.325	.100	1.069	.050	.576
Trammel net	.579	.739	.359	.483	.070	.635	.057	.417
Hoop net	.025	.000	.013	.208	.019	.059	.050	.053
Mean	.426	.738	.237	.339	.063	.588	.052	.349
Longnose gar								
Gill net	.425	.250	.128	.163	.013	.569	.338	.269
Trammel net	.416	.071	.079	.012	.000	.600	.226	.201
Hoop net	.003	.013	.003	.023	.000	.025	.013	.011
Mean	.281	.111	.070	.066	.004	.398	.192	.160
Shortnose gar								
Gill net	5.488	1.263	.934	2.088	.163	4.238	.757	2.133
Trammel net	3.704	1.199	.894	.655	.061	3.676	.467	1.522
Hoop net	.038	.019	.025	.073	.009	.088	.000	.036
Mean	3.077	.827	.618	.939	.078	2.667	.408	1.231
Flathead catfish								
Gill net	.013	.038	.094	.025	.000	.063	.013	.035
Trammel Net	.059	.048	.276	.114	.004	.191	.020	.102
Hoop net	.100	.116	.075	.105	.010	.080	.019	.072
Mean	.057	.067	.148	.081	.005	.111	.017	.069

Table I-8 Continued Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1966.

Species of fish	Sampling Station							Total for Year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
Spotted gar								
Gill net	.013	.000	.025	.188	.038	.219	3.271	.536
Trammel net	.004	.000	.004	.042	.131	.133	1.875	.313
Hoop net	.000	.000	.000	.006	.000	.003	.003	.002
Mean	.006	.000	.010	.079	.056	.118	1.716	.284
Sauger								
Gill net	.363	.425	.225	.138	.000	.444	.013	.230
Trammel net	.250	.188	.045	.079	.000	.108	.000	.096
Hoop Net	.077	.013	.007	.000	.000	.003	.000	.014
Mean	.230	.209	.092	.072	.000	.185	.004	.113
Smallmouth Buffalo								
Gill net	.075	.125	.088	.175	.163	.325	.498	.207
Trammel net	.586	.300	1.090	.614	1.013	.422	1.978	.858
Hoop net	.137	.170	.267	.150	.221	.092	.265	.186
Mean	.266	.198	.482	.313	.466	.280	.914	.417
Carp								
Gill net	.063	.100	.075	.438	.300	.169	.053	.171
Trammel net	.762	.843	.442	1.336	1.082	.467	.423	.765
Hoop net	.204	.296	.078	.448	.399	.044	.006	.211
Mean	.343	.413	.198	.741	.594	.227	.161	.382
River Carpsucker								
Gill net	1.038	1.275	.356	.563	.025	1.353	.075	.669
Trammel net	2.999	2.024	1.122	.952	.021	.800	.033	1.136
Hoop net	.203	.138	.150	.118	.003	.161	.009	.112
Mean	1.413	1.146	.543	.544	.016	.771	.039	.639
Freshwater Drum								
Gill net	.875	.625	1.213	.975	.529	.284	.140	.663
Trammel net	.442	.450	.623	.500	.276	.776	.095	.452
Hoop net	.261	.239	.339	.327	.291	.375	.226	.294
Mean	.526	.438	.725	.601	.365	.478	.154	.470
Goldeye								
Gill net	1.013	.838	.213	.150	.013	1.822	.013	.580
Trammel net	.125	.042	.049	.054	.000	.929	.000	.171
Hoop net	.039	.063	.023	.027	.000	.033	.000	.026
Mean	.392	.314	.095	.077	.004	.928	.004	.259
Skipjack Herring								
Gill net	.725	.975	1.553	1.000	3.125	1.641	.287	1.329
Trammel net	.321	.070	.709	.179	.750	.748	.063	.406
Hoop net	.024	.009	.029	.018	.047	.026	.000	.022
Mean	.357	.351	.764	.399	1.307	.805	.117	.586

Table I-8 Continued Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1966.

Species of fish	Sampling Station Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Total for Year
Striped mullet								
Gill net	.000	.000	.000	.088	1.163	.500	2.803	.651
Trammel net	.000	.000	.004	.050	.100	.146	5.256	.794
Hoop net	.000	.000	.000	.003	.044	.003	.016	.009
Mean	.000	.000	.001	.047	.436	.216	2.692	.485
Gizzard shad								
Gill net	9.350	9.525	6.516	4.925	5.813	9.678	6.283	7.441
Trammel net	3.587	3.889	2.516	3.897	3.814	4.996	3.994	3.813
Hoop net	.295	.228	.634	1.373	.290	.622	.084	.504
Mean	4.411	4.547	3.222	3.398	3.306	5.099	3.454	3.920
Threadfin shad								
Gill net	.288	.888	1.763	2.650	8.708	3.019	.338	2.522
Trammel net	.000	.000	.000	.000	.004	.000	.004	.001
Hoop net	.000	.000	.041	.000	.063	.000	.000	.015
Mean	.096	.296	.601	.883	2.925	1.006	.114	.846
Golden shiner								
Gill net	.000	.013	.013	.000	.000	.000	.063	.013
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.004	.004	.000	.000	.000	.021	.004
Shovelnose Sturgeon								
Gill net	.138	.000	.000	.000	.000	.000	.000	.020
Trammel net	.283	.008	.005	.000	.000	.004	.000	.043
Hoop net	.006	.000	.000	.000	.000	.000	.000	.001
Mean	.142	.003	.002	.000	.000	.001	.000	.021
Largescale Menhaden								
Gill net	.000	.000	.000	.000	8.113	.050	.300	1.209
Trammel net	.000	.000	.000	.000	.563	.000	.000	.080
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.000	.000	2.892	.017	.100	.430

Table I-8a Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1967.

Species of fish	Sampling Station							Total for Year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
White bass								
Gill net	.705	.238	.303	.656	.259	.788	.958	.558
Trammel net	.354	.033	.193	.366	.122	.569	.304	.277
Hoop net	.096	.007	.038	.025	.018	.008	.004	.028
Mean	.385	.093	.178	.349	.133	.455	.422	.288
Yellow bass								
Gill net	.583	.056	.078	.456	.231	.731	.597	.390
Trammel net	.047	.005	.011	.004	.192	.137	.020	.059
Hoop net	.000	.000	.000	.003	.004	.020	.000	.004
Mean	.210	.020	.030	.154	.142	.296	.206	.151
Blue catfish								
Gill net	.159	.553	.731	3.141	3.431	.916	.301	1.319
Trammel net	.073	.534	.577	1.971	.547	.672	.058	.633
Hoop net	.038	.035	.012	.027	.223	.229	.038	.086
Mean	.090	.374	.440	1.713	1.400	.606	.132	.679
Channel catfish								
Gill net	.188	.338	.731	1.203	4.250	.266	1.106	1.155
Trammel net	.082	.154	.186	.181	.498	.094	.159	.193
Hoop net	.183	.148	.034	.012	.622	.059	.047	.158
Mean	.151	.213	.317	.465	1.790	.140	.437	.502
Black crappie								
Gill net	.078	.059	.344	.159	.063	.169	.044	.131
Trammel net	.005	.041	.221	.079	.146	.190	.071	.108
Hoop net	.000	.000	.016	.004	.064	.004	.086	.025
Mean	.028	.033	.194	.081	.091	.121	.067	.088
White crappie								
Gill net	.172	.344	.734	.759	.141	.772	.271	.456
Trammel net	.235	.439	1.111	.187	.166	.621	.048	.401
Hoop net	.027	.000	.025	.019	.008	.015	.070	.023
Mean	.145	.261	.623	.322	.105	.469	.130	.294
Longnose gar								
Gill net	.449	.172	.156	.094	.047	.481	.130	.218
Trammel net	.213	.063	.055	.031	.005	.342	.140	.121
Hoop net	.055	.031	.012	.000	.000	.008	.000	.015
Mean	.239	.089	.074	.042	.017	.277	.090	.118
Shortnose gar								
Gill net	2.882	.884	.609	1.466	.216	1.916	.939	1.273
Trammel net	2.291	.470	.513	.409	.078	1.548	.582	.842
Hoop net	.183	.033	.104	.015	.000	.038	.000	.053
Mean	1.785	.462	.409	.630	.098	1.167	.507	.723
Flathead Catfish								
Gill net	.000	.013	.063	.016	.000	.000	.000	.013
Trammel net	.073	.111	.243	.156	.000	.104	.000	.098
Hoop net	.070	.076	.115	.031	.000	.027	.000	.046
Mean	.048	.067	.140	.068	.000	.044	.000	.052

Table I-8a Continued Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1967.

Species of fish	Sampling Station Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	for Year
Skipjack Herring								
Gill net	.484	.375	1.053	3.322	5.638	1.175	.314	1.766
Trammel net	.187	.377	.276	.563	1.842	1.415	.031	.670
Hoop net	.203	.000	.060	.000	.024	.027	.000	.045
Mean	.291	.251	.463	1.295	2.501	.872	.115	.827
Striped Mullet								
Gill net	.000	.000	.063	.028	2.628	.531	7.620	1.553
Trammel net	.000	.000	.000	.019	.549	.435	4.934	.848
Hoop net	.000	.000	.000	.000	.016	.012	.016	.006
Mean	.000	.000	.021	.016	1.064	.326	4.190	.802
Gizzard shad								
Gill net	8.397	7.778	4.763	9.406	12.009	8.600	10.552	8.786
Trammel net	2.391	2.728	6.691	3.350	4.451	7.974	3.960	4.506
Hoop net	.542	.198	2.200	.129	.322	1.154	.027	.653
Mean	3.777	3.568	4.551	4.295	5.594	5.909	4.846	4.649
Threadfin shad								
Gill net	.313	1.125	2.766	8.569	13.744	3.844	.259	4.374
Trammel net	.000	.000	.000	.005	.000	.005	.010	.003
Hoop net	.000	.000	.005	.000	.000	.004	.000	.001
Mean	.104	.375	.924	2.858	4.581	1.284	.090	1.459
Golden Shiner								
Gill net	.000	.000	.063	.000	.000	.000	.000	.009
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.021	.000	.000	.000	.000	.003
Shovelnose Sturgeon								
Gill net	.018	.016	.000	.000	.000	.000	.000	.005
Trammel net	.004	.033	.011	.000	.000	.004	.000	.007
Hoop net	.004	.006	.000	.000	.000	.008	.000	.003
Mean	.009	.018	.004	.000	.000	.004	.000	.005
Largescale Menhaden								
Gill net	.000	.000	.000	.000	1.281	.000	.021	.186
Trammel net	.000	.000	.000	.000	.037	.000	.000	.005
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.000	.000	.439	.000	.007	.064

Table I-8a Continued Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi Rivers during 1967.

Species of fish	Sampling Station Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	Total for Year
Spotted gar								
Gill net	.000	.000	.016	.125	.047	.234	3.490	.559
Trammel net	.000	.000	.008	.026	.026	.026	2.350	.348
Hoop net	.000	.000	.000	.000	.000	.004	.012	.002
Mean	.000	.000	.008	.050	.024	.088	1.951	.303
Sauger								
Gill net	.375	1.588	.684	.253	.047	.294	.013	.465
Trammel net	.422	.439	.136	.041	.005	.106	.005	.165
Hoop net	.023	.021	.007	.004	.000	.010	.000	.009
Mean	.273	.683	.276	.099	.017	.137	.006	.213
Smallmouth Buffalo								
Gill net	.098	.053	.094	.119	.047	.216	1.939	.367
Trammel net	.582	.658	.582	.285	1.628	.825	2.183	.963
Hoop net	.102	.189	.139	.082	.144	.169	.082	.130
Mean	.261	.300	.272	.162	.606	.403	1.401	.486
Carp								
Gill net	.031	.031	.172	.063	.609	.078	.224	.173
Trammel net	.547	.313	.249	.438	1.495	.235	.334	.516
Hoop net	.067	.078	.124	.074	.179	.146	.000	.095
Mean	.215	.141	.182	.192	.761	.153	.186	.261
River carpsucker								
Gill net	2.750	3.353	1.556	.622	.078	.628	.069	1.294
Trammel net	3.479	5.767	2.330	1.036	.106	1.648	.009	2.054
Hoop net	.538	.295	.383	.243	.015	.208	.013	.242
Mean	2.256	3.138	1.423	.634	.066	.828	.030	1.196
Freshwater Drum								
Gill net	.299	1.269	.453	1.888	.903	.266	.655	.819
Trammel net	.307	.499	.649	.666	.566	.316	.122	.446
Hoop net	.694	.389	.462	.647	.359	.503	.277	.476
Mean	.433	.719	.521	1.067	.609	.362	.351	.580
Goldeye								
Gill net	1.587	.513	.172	.388	.000	.853	.013	.504
Trammel net	.161	.063	.013	.020	.005	.247	.026	.076
Hoop net	.157	.042	.026	.000	.000	.039	.000	.038
Mean	.635	.206	.070	.136	.002	.380	.013	.206

Table I-8b Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1968.

Species of fish	Sampling Station							Total for Year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
White bass								
Gill net	.531	.125	.438	.455	.188	.641	.750	.447
Trammel net	.399	.026	.215	.135	.073	.162	.094	.158
Hoop net	.094	.004	.039	.024	.000	.023	.004	.027
Mean	.341	.052	.231	.205	.087	.275	.283	.211
Yellow bass								
Gill net	.328	.016	.047	.250	.031	.063	.672	.201
Trammel net	.099	.010	.021	.016	.031	.005	.057	.034
Hoop net	.004	.000	.000	.004	.004	.004	.000	.002
Mean	.144	.009	.023	.090	.022	.024	.243	.079
Blue catfish								
Gill net	1.406	.500	1.141	2.717	2.250	.828	.469	1.330
Trammel net	.085	.255	.520	.870	1.125	.651	.187	.528
Hoop net	.016	.024	.024	.020	.121	.063	.020	.041
Mean	.502	.260	.562	1.202	1.165	.514	.225	.633
Channel catfish								
Gill net	.453	.250	.406	1.192	5.219	.781	.563	1.266
Trammel net	.358	.156	.042	.089	.698	.183	.099	.232
Hoop net	.044	.082	.012	.039	.473	.020	.004	.096
Mean	.285	.163	.153	.440	2.130	.328	.222	.532
Black crappie								
Gill net	.000	.063	.188	.181	.000	.156	.047	.091
Trammel net	.000	.031	.181	.078	.011	.135	.250	.098
Hoop net	.008	.004	.004	.000	.000	.004	.012	.005
Mean	.003	.033	.124	.086	.004	.098	.103	.064
White crappie								
Gill net	.344	.188	.813	.685	.063	1.656	.109	.551
Trammel net	.181	.266	.846	.464	.183	.552	.037	.361
Hoop net	.000	.008	.016	.008	.004	.004	.004	.006
Mean	.175	.154	.558	.386	.083	.737	.050	.306
Longnose gar								
Gill net	.172	.266	.125	.063	.078	.531	.125	.194
Trammel net	.174	.125	.026	.005	.000	.130	.115	.082
Hoop net	.004	.004	.004	.000	.000	.004	.000	.002
Mean	.117	.132	.052	.023	.026	.222	.080	.093
Shortnose gar								
Gill net	3.594	1.078	1.219	.991	.031	2.047	.688	1.378
Trammel net	4.217	.344	.605	.443	.010	.854	.234	.958
Hoop net	.111	.039	.055	.008	.000	.012	.000	.032
Mean	2.641	.487	.626	.481	.014	.971	.307	.790
Flathead Catfish								
Gill net	.031	.016	.031	.031	.000	.000	.000	.016
Trammel net	.043	.120	.295	.146	.000	.021	.016	.092
Hoop net	.049	.027	.020	.004	.004	.039	.012	.022
Mean	.041	.054	.115	.060	.001	.020	.009	.043

Table I-8b Continued Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1968.

Species of fish	Sampling Station							for Year
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	
Spotted gar								
Gill net	.000	.000	.016	.194	.016	.156	1.938	.331
Trammel net	.000	.000	.000	.026	.000	.042	1.328	.199
Hoop net	.000	.000	.000	.000	.008	.000	.000	.001
Mean	.000	.000	.005	.073	.008	.066	1.089	.177
Sauger								
Gill net	.969	.766	.203	.159	.031	.250	.016	.342
Trammel net	.309	.490	.073	.011	.000	.052	.005	.134
Hoop net	.070	.024	.016	.000	.000	.008	.000	.017
Mean	.449	.427	.097	.057	.010	.103	.007	.164
Smallmouth Buffalo								
Gill net	.125	.047	.250	.112	.078	.344	.953	.273
Trammel net	.373	.266	.654	.266	.869	1.312	.974	.673
Hoop net	.047	.055	.039	.039	.090	.192	.066	.075
Mean	.182	.123	.314	.139	.346	.616	.664	.341
Carp								
Gill net	.188	.109	.234	.049	.359	.125	.141	.172
Trammel net	.816	.458	.918	.563	.731	.427	.458	.624
Hoop net	.023	.062	.086	.031	.141	.055	.000	.057
Mean	.342	.210	.413	.214	.410	.202	.200	.284
River carpsucker								
Gill net	.484	2.328	1.125	.491	.031	1.375	.109	.849
Trammel net	3.333	5.177	2.266	.870	.078	3.250	.026	2.143
Hoop net	1.033	.426	.434	.070	.012	.094	.004	.296
Mean	1.617	2.644	1.275	.477	.040	1.573	.046	1.096
Freshwater Drum								
Gill net	1.406	.750	.328	.601	.813	1.703	.391	.856
Trammel net	.597	.646	.293	.417	.486	.406	.162	.430
Hoop net	.153	.113	.055	.223	.430	.242	.121	.191
Mean	.719	.503	.225	.414	.576	.784	.225	.492
Goldeye								
Gill net	3.156	.719	.422	.156	.000	.234	.016	.672
Trammel net	.141	.110	.057	.011	.000	.057	.000	.054
Hoop net	.160	.024	.063	.004	.000	.000	.000	.036
Mean	1.152	.284	.181	.057	.000	.097	.005	.254

Table I-8b Continued Number of fish caught per net day for 23 of the more abundant species of fish in the Mississippi and Atchafalaya Rivers during 1968.

Species of fish	Sampling Station							
	Hickman	Tunica	Vicksburg	Tarbert Landing	Luling	Simmesport	Morgan City	for Year
Skipjack Herring								
Gill net	.266	.703	1.094	.891	1.344	3.516	.000	1.116
Trammel net	.222	.459	1.497	.120	1.391	1.016	.021	.675
Hoop net	.017	.047	.094	.082	.039	.012	.000	.042
Mean	.168	.403	.895	.364	.925	1.515	.007	.611
Striped Mullet								
Gill net	.000	.000	.000	.031	1.641	.078	3.000	.679
Trammel net	.000	.000	.005	.031	.500	.547	2.552	.519
Hoop net	.000	.000	.000	.000	.004	.008	.004	.002
Mean	.000	.000	.002	.021	.715	.211	1.852	.400
Gizzard shad								
Gill net	7.734	8.203	7.734	5.817	3.891	5.406	5.438	6.318
Trammel net	3.644	2.792	3.264	1.661	1.394	3.974	1.271	2.571
Hoop net	.173	.164	1.692	.309	.574	.391	.020	.475
Mean	3.850	3.720	4.230	2.596	1.953	3.257	2.243	3.121
Threadfin shad								
Gill net	.109	1.984	7.578	9.804	1.156	5.797	.234	3.809
Trammel net	.000	.005	.005	.000	.000	.021	.000	.004
Hoop net	.000	.000	.012	.027	.000	.024	.000	.009
Mean	.036	.663	2.532	3.277	.385	1.947	.078	1.274
Golden Shiner								
Gill net	.000	.016	.031	.000	.000	.000	.000	.007
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.066	.004	.000	.000	.000	.000	.010
Mean	.000	.027	.012	.000	.000	.000	.000	.006
Shovelnose Sturgeon								
Gill net	.016	.000	.000	.000	.016	.000	.000	.005
Trammel net	.005	.042	.005	.000	.005	.016	.000	.010
Hoop net	.000	.004	.000	.000	.000	.000	.000	.001
Mean	.007	.015	.002	.000	.007	.005	.000	.005
Largescale Menhaden								
Gill net	.000	.000	.000	.000	.578	.000	.031	.087
Trammel net	.000	.000	.000	.000	.000	.000	.000	.000
Hoop net	.000	.000	.000	.000	.000	.000	.000	.000
Mean	.000	.000	.000	.000	.193	.000	.010	.029

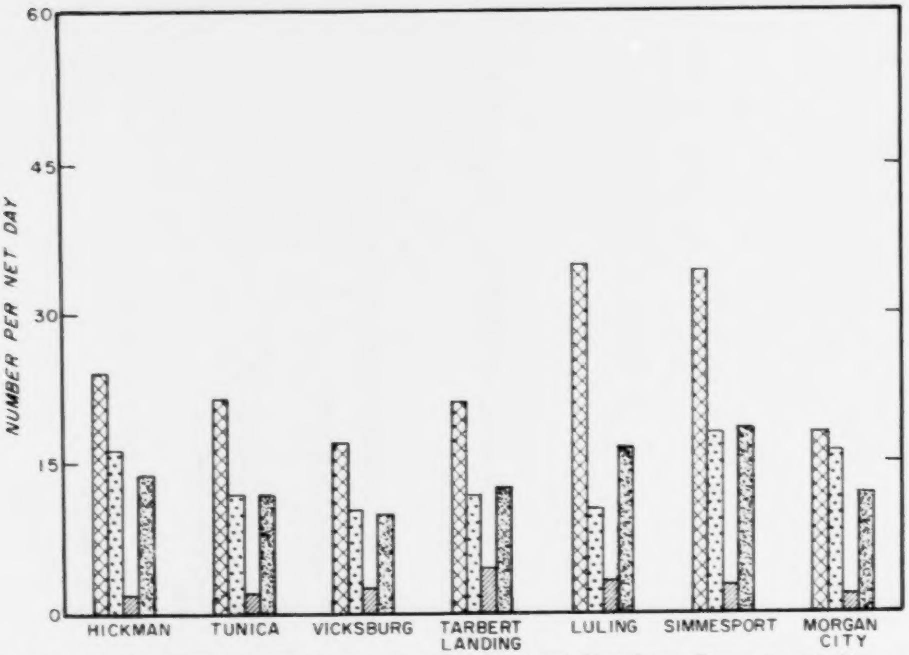

FIG. I-2 Number of fish caught per day from Mississippi and Atchafalaya Rivers by sampling stations during 1966

▨ Gill Nets
▨ Trammel Nets
▨ Hoop Nets
▨ Mean Catch Rate

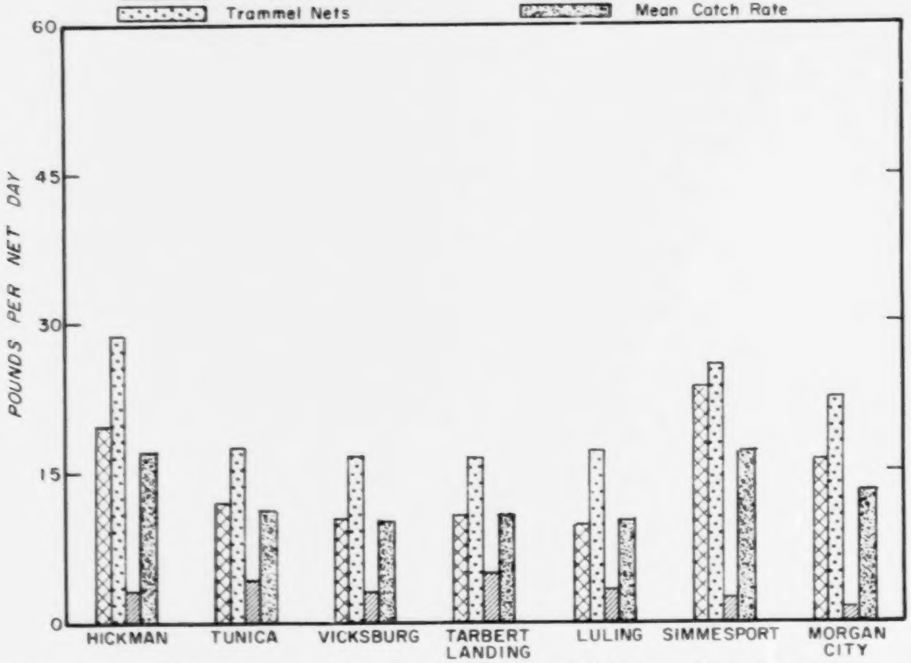

FIG. I-3 Pounds of fish caught per net day from Mississippi and Atchafalaya Rivers by sampling stations during 1966

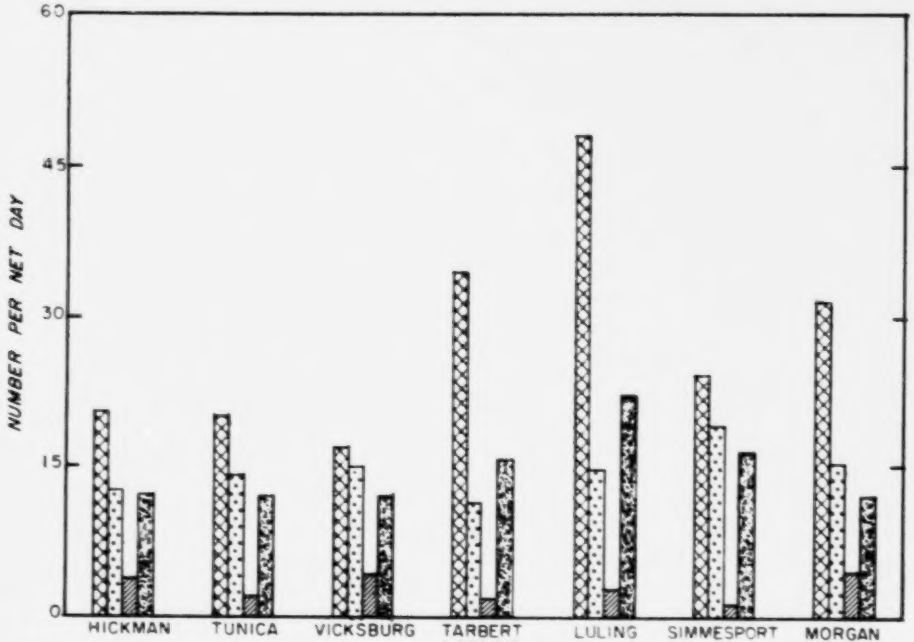

FIG I-2a Number of fish caught per day from Mississippi and Atchafalaya Rivers by sampling stations during 1967

▨ Gill Nets
▨ Trammel Nets
▨ Hoop Nets
▨ Mean Catch Rate

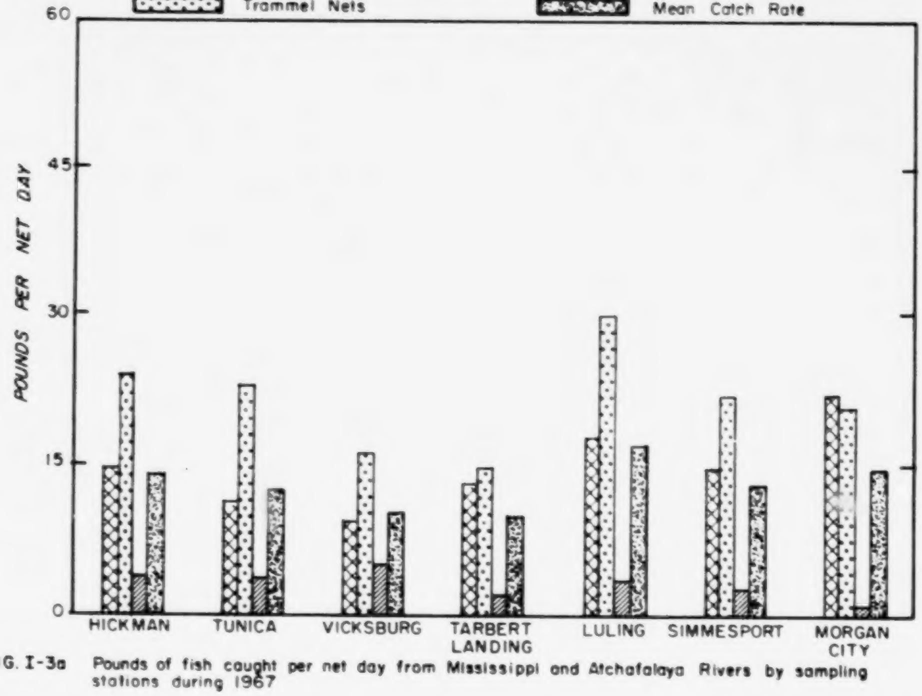

FIG. I-3a Pounds of fish caught per net day from Mississippi and Atchafalaya Rivers by sampling stations during 1967

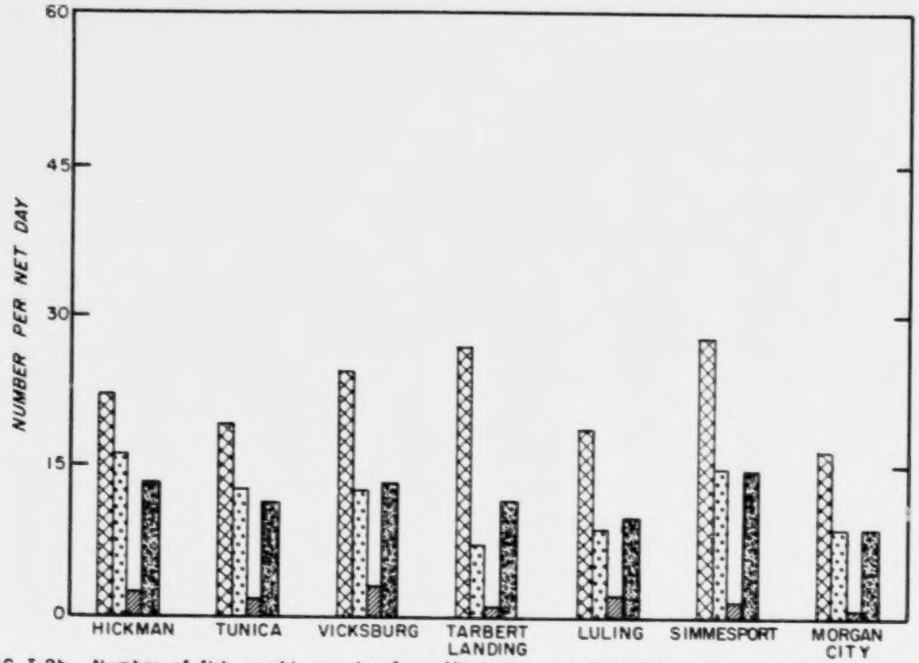

FIG. I-2b Number of fish caught per day from Mississippi and Atchafalaya Rivers by sampling stations during 1968

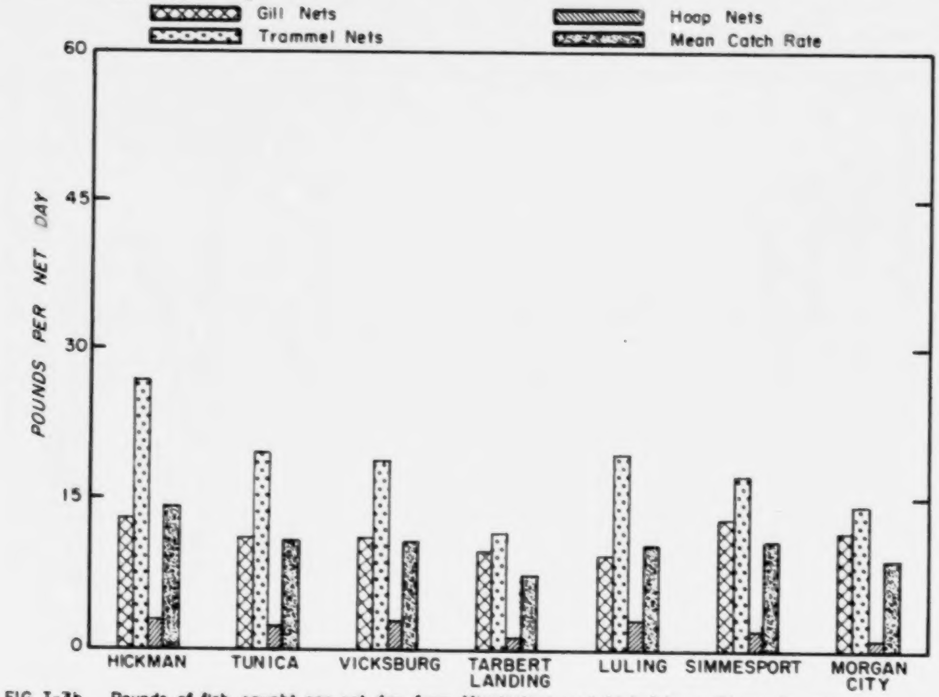

FIG. I-3b Pounds of fish caught per net day from Mississippi and Atchafalaya Rivers by sampling stations during 1968

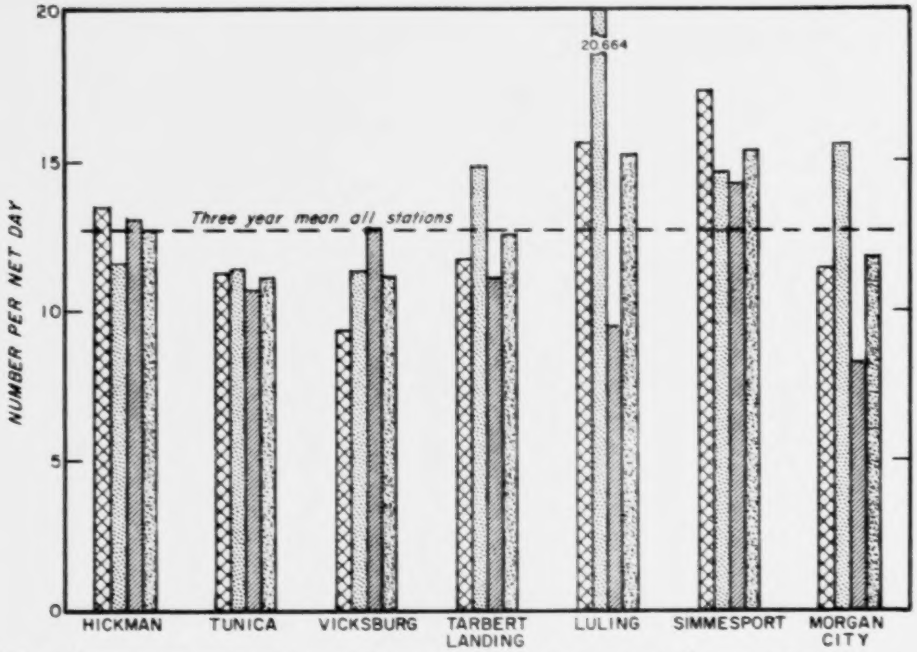

FIG. I-4 Annual mean number of fish caught per net day for all gear at each of seven stations during 1966, 1967, 1968, three year mean for each station, and three year mean for all stations

▨ 1966
▨ 1967
▨ 1968
▨ Mean of three yearly means

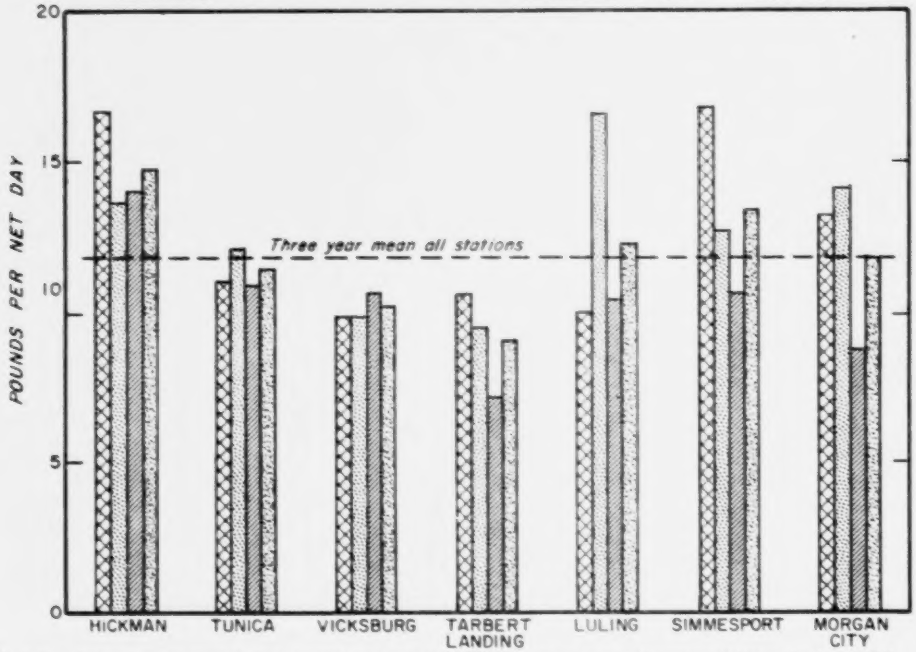

FIG. I-5 Annual mean pounds fish caught per net day for all gear at each of seven stations during 1966, 1967, 1968, three year mean for each station, and three year mean for all stations